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SOUTH TOBACCO CREEK MANURED WATERSHED RUNOFF STUDY, 1998 - 2001

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SUMMARY

A study was conducted in the South Tobacco Creek Watershed from 1998 to 2001 to compare surface water quality runoff characteristics between fields amended with inorganic commercial fertilizer and organic (hog manure) fertilizer. Water runoff samples were also collected from a forage field and a relatively undisturbed natural wooded area. The study was conducted with the collaboration of producers within the watershed and various agencies that included Manitoba Conservation[1], Environment Canada, Manitoba Agriculture and Food, Prairie Farm Rehabilitation Administration, Manitoba Pork Est[2], the Manitoba Livestock Manure Management Initiative and the Agricultural Research and Development Initiative.

There was no indication that application of hog manure onto land during the fall by broadcast spreading and incorporation into the soil within 48 – 72 hours caused greater fecal coliform values in spring runoff than from locations without manure applications. Mean fecal coliform bacteria values from the field applied with hog manure were within ranges from the Forage Field, the Natural Wooded Area, and fields in the Twin Watershed that did not receive manure.

Concentrations of nutrients and organic carbon were significantly higher in runoff from the Manured Watershed field than the other study field sites when an appreciable amount of runoff (481 $m^3 ha^{-1}$) occurred from this site during 1998. In 1998, mean total nitrogen and phosphorus concentrations were 18.4 mg L^{-1} and 2.3 mg L^{-1}, respectively. Meanwhile, concentrations of nitrogen and phosphorus from the Natural Wooded Area, Forage Field, Zero-till field and Conventional-till field ranged from approximately 0.4 – 2.9 mg L^{-1} and < 0.1 – 0.54 mg L^{-1}, respectively. The relatively substantive runoff volume during 1998 also coincided with a relatively high areal loss (kg ha^{-1}) of nutrients from the Manured Watershed field compared to the Conventional-till and Zero-till fields. Total nitrogen loss from the Manured Watershed field was approximately 8.63 kg ha^{-1} compared to between only 1.72 – 1.77 kg ha^{-1} from the Zero-till and Conventional-till fields, despite the Manured Watershed field being only about one quarter the size of the other fields. Higher nutrient losses from the Manured Watershed field in 1998 were considered due to much higher nutrient values in the upper 15 cm of soil of the Manured Watershed than the other fields.

Nutrient loss from the Manured Watershed field was much lower than from the Conventional-till or Zero-till fields between 1999 – 2001 even though nutrient values in soil were usually above agronomic rates and continued to be higher than the Zero-till or Conventional-till fields during spring runoff. Total nitrogen loss from the Manured Watershed field was < 0.1 kg ha^{-1} compared to between 0.81 – 3.67 kg ha^{-1} from the Conventional-till and Zero-till fields. The main reason for this situation was due to poor

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[1] Formerly known as Manitoba Environment prior to amalgamation with Manitoba Natural Resources in October 1999.

[2] Manitoba Pork Establishment, 750 Marion Street, Winnipeg MB.

runoff from this field in those years. Runoff from the Manured Watershed field was not measurable in 2000 and only ranged between 2% - 6 % of the 1998 value during 1999 and 2001. This condition greatly reduced the opportunity for nutrient loss in surface runoff.

The mean total nitrogen concentration from the Conventional-till field during spring runoff 1999 was 16.4 mg L^{-1} and was the second highest value observed during this study. The occurrence of this concentration was attributed to the addition of anhydrous ammonia-N during the previous fall of 1998. Although anhydrous ammonia-N was also applied to the Conventional-till field in the fall of 1999 at the same application rate as 1998, the absence of runoff from the Conventional-till field during 2000 prevented a repeated occurrence of relatively high nitrogen concentrations in spring runoff.

Mean total phosphorus concentrations in runoff from the fields were usually < 2 mg L^{-1}, except for the Manured Watershed and Zero-till fields during 1998 and 2001, respectively. During these years, mean total phosphorus values from the Manured Watershed and Zero-till fields were approximately 2.3 mg L^{-1} and 2.7 mg L^{-1}, respectively. Mean phosphorus concentrations from the Forage Field and Zero-till field appeared to be slightly increasing each successive year and this was thought to be likely due to increased organic build up on the soil surface over time. The dissolved form of phosphorus as well as the dissolved forms of nitrogen and organic carbon comprised the major portion the total concentrations for each variable.

Mean suspended solid concentrations were consistently higher from the Conventional-till field than other field sites. This was considered due to more surface soil exposure and less organic matter on the soil surface to help reduce soil and other fine particulate matter transport.

The total nutrient losses from fields were usually lower from precipitation events in the post-spring runoff period than during spring mainly because there were more days with runoff in spring to provide more volume.

The nutrient content of hog manure from a single operation was not consistent between years. Nitrogen content varied more than phosphorus. Nitrogen was fairly consistent for samples from the first two years of the study and a sample collected a couple of years prior to the study, and was less consistent for the later two years of study. This variation affects estimates for determining fertilization rates and emphasizes the importance for soil testing areas receiving hog manure, especially on land that receives repeated annual applications.

Total phosphorus values in soil samples collected from the Manured Watershed field during fall showed a consistent, slightly increasing trend with consecutive annual applications of hog manure over a four-year period. This was attributed to application rates based upon N requirements and more P than needed for crops was incidentally added while meeting nitrogen requirements.

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RÉSUMÉ ANALYTIQUE

Une étude a été menée dans le bassin hydrographique du ruisseau South Tobacco de 1998 à 2001 pour comparer la qualité des eaux de surface et les caractéristiques des eaux de ruissellement entre des champs fertilisés d'une part avec de l'engrais commercial inorganique et, d'autre part, avec de l'engrais organique (fumier de porc). On a également prélevé des échantillons d'eau de ruissellement d'un champ de fourrage et une aire boisée à l'état quasi naturel. Cette étude a été menée avec la collaboration de producteurs établis dans le bassin hydrographique et de divers organismes, dont Conservation Manitoba[1], Environnement Canada, Agriculture et Alimentation Manitoba, l'Administration du rétablissement agricole des Prairies, Manitoba Pork Est[2], Manitoba Livestock Manure Management Initiative et Agricultural Research and Development Initiative.

Rien n'indique que l'épandage de fumier de porc en couverture et son incorporation dans un délai de 48 à 72 heures ont entraîné une densité plus élevée de coliformes fécaux dans les eaux de ruissellement printanières que dans celles qui provenaient de champs qui n'avaient pas été fertilisés au fumier. La densité moyenne de bactéries de coliformes fécaux dans les champs fertilisés au fumier de porc était similaire à celle du champ de fourrage, de l'aire boisée naturelle et des deux champs jumelés du bassin hydrographique qui n'avaient pas reçu de fumier.

Les concentrations d'éléments nutritifs et de carbone organique étaient sensiblement plus fortes dans les eaux de ruissellement du champ ayant reçu une fumure dans le bassin hydrographique qu'aux autres sites de l'étude où l'on a observé une quantité appréciable (481 $m^3\ ha^{-1}$) d'eaux de ruissellement qui provenaient de ce site en 1998. En 1998, les concentrations totales moyennes d'azote et de phosphore étaient respectivement de 18,4 mg L^{-1} et de 2,3 mg L^{-1}. Pendant la même période, les concentrations d'azote et de phosphore de l'aire boisée naturelle, du champ de fourrage, du champ qui a fait l'objet d'un semis direct et de celui auquel on a appliqué la méthode classique de travail du sol s'échelonnaient approximativement comme suit, respectivement : 0,4 – 2,9 mg L^{-1} et < 0,1 – 0,54 mg L^{-1}. Le volume relativement substantiel d'eaux de ruissellement en 1998 coïncidait également avec une perte superficique relativement importante (kg ha^{-1}) d'éléments nutritifs dans le champ ayant été fertilisé dans le bassin hydrographique par rapport aux champs qui avaient fait l'objet d'un semis direct ou d'une méthode classique de travail du sol. La perte totale en azote dans le champ fertilisé du bassin hydrographique était d'environ 8,63 kg ha^{-1}, alors qu'elle n'était que de 1,72 – 1,77 kg ha^{-1} dans les champs ayant fait l'objet d'un semis direct ou d'une méthode classique de travail du sol, même si la superficie du champ

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[1] Autrefois connu sous le nom d'Environnement Manitoba, avant sa fusion avec Ressources naturelles Manitoba en octobre 1999.

[2] Manitoba Pork Establishment, 750 rue Marion, Winnipeg (Manitoba).

fertilisé dans le bassin hydrographique ne représentait que le quart environ de celle des autres champs. Les pertes plus élevées en éléments nutritifs dans le champ fertilisé du bassin hydrographique que l'on a observées en 1998 s'expliquent par la teneur beaucoup plus forte en éléments nutritifs dans la couche supérieure de 15 cm du sol du champ fertilisé dans le bassin hydrographique que dans les autres champs.

La perte en éléments nutritifs du champ fertilisé dans le bassin hydrographique était de beaucoup inférieure à celle des champs qui avaient fait l'objet d'un semis direct ou d'une méthode classique de travail du sol de 1999 à 2001, même si la teneur en éléments nutritifs du sol était généralement supérieure aux taux agronomiques et se maintenait au delà de celle des champs ayant fait l'objet d'un semis direct ou d'une méthode classique de travail du sol pendant le ruissellement printanier. La perte totale en azote du champ fertilisé dans le bassin hydrographique était de < 0,1 kg ha^{-1}, comparativement à une perte de 0,81 à 3,67 kg ha^{-1} dans les champs ayant fait l'objet d'un semis direct ou d'une méthode classique de travail du sol. Cette situation s'explique surtout par la faible quantité d'eaux de ruissellement provenant de ce champ pendant cette période. En 1999 et 2001, les eaux de ruissellement provenant du champ fertilisé au fumier dans le bassin hydrographique, non mesurables en 2000, n'ont atteint que de 2 % à 6 % de la quantité de 1998. Cet état de choses a sensiblement réduit la possibilité de perte en éléments nutritifs dans les eaux de ruissellement de surface.

La concentration totale moyenne d'azote provenant du champ où le sol avait été labouré selon la méthode classique était de 16,4 mg L^{-1} pendant le ruissellement printanier, et la densité observée au cours de cette étude se classait deuxième. On a attribué cette concentration à l'ajout d'azote d'ammoniac anhydre au cours de l'automne précédent de 1998. Quoiqu'en automne 1999, on épandît la même dose d'azote d'ammoniac anhydre qu'en 1998 dans le champ dont le sol avait été travaillé selon la méthode classique, en 2000 l'absence d'eaux de ruissellement provenant du champ travaillé selon la méthode classique empêcha une occurrence répétée de concentrations d'azote relativement élevées dans les eaux de ruissellement printanières.

Les concentrations moyennes totales en phosphore dans les eaux de ruissellement provenant des champs étaient généralement de < 2 mg L^{-1}, sauf dans le cas du champ fertilisé au fumier dans le bassin hydrographique et du champ ayant fait l'objet d'un semis direct en 1998 et 2001, respectivement. Au cours de ces années-là, la teneur moyenne totale en phosphore dans le champ fertilisé au fumier dans le bassin hydrographique et dans le champ ayant fait l'objet d'un semis direct était d'environ 2,3 mg L^{-1} et 2,7 mg L^{-1}, respectivement. Les concentrations moyennes en phosphore du champ de fourrage et du champ ayant fait l'objet d'un semis direct ont enregistré une légère hausse d'année en année, ce qui s'explique probablement par l'accumulation de matière organique à la surface du sol au fil du temps. La dilution de phosphore ainsi que les dilutions d'azote et de carbone organique comprenaient la plus grande part des concentrations totales pour chaque variable.

Les concentrations moyennes de matières solides suspendues étaient en général plus fortes dans le cas du champ labouré selon la méthode classique que dans les autres sites. Ceci s'explique par une plus grande surface de couche arable exposée et par une quantité moindre de matières organiques à la surface du sol, facteurs qui ont contribué à réduire le transport du sol et d'autres particules fines.

La perte totale en éléments nutritifs des champs était généralement plus faible dans le cas de précipitations au cours de la période de ruissellement post-printanière que durant le printemps, parce que le nombre de jours où se produit le ruissellement au printemps était plus grand et faisait donc augmenter le volume.

La teneur en éléments nutritifs du fumier de porc provenant d'une seule porcherie variait d'une année à l'autre. La teneur en azote a connu des variations plus fortes que le phosphore. Les échantillons des deux premières années de l'étude ainsi qu'un échantillon prélevé deux ans avant l'étude présentaient une teneur en azote assez uniforme, mais cette uniformité était moins grande pour les deux dernières années de l'étude. Cette variation influe sur les évaluations qui servent à déterminer le dosage de la fertilisation, et souligne l'importance pour les aires soumises à des analyses de sol de recevoir du fumier de porc, surtout pour les terres sur lesquelles on procède à des épandages annuels répétés.

La densité totale de phosphore dans les échantillons de sol prélevés dans le champ fertilisé au fumier en automne dans le bassin hydrographique marque une légère tendance constante à la hausse dans le cas d'épandages de fumier de porc annuels consécutifs au cours d'une période de quatre ans. Ceci est attribué au dosage de l'épandage d'après les besoins en azote et à une quantité de phosphore supérieure aux besoins des cultures qui a été ajoutée mais qui correspondait par ailleurs aux besoins en azote.

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1.0 INTRODUCTION

Expansion of the hog industry in Manitoba during the 1990s increased public concerns about the potential for environmental contamination partially because of problems associated with intensive agricultural operations previously reported in the Netherlands and the United States. During the 1980s it was evident in the Netherlands that many livestock operations were producing more nutrients than the relatively limited land base could safely utilize and an imbalance from over applications of manure affected some groundwater drinking supplies (Anonymous 1995). Nutrient emissions from agricultural sources were the dominant source of nutrient loads to freshwater in the Netherlands and requirements such as on-farm mineral bookkeeping were introduced to get greater controls on nutrient additions to land (Diederik *et al.* 1998, Boers 1996). Environmental accidents of large scale hog operations in North Carolina during the mid 1990s caused excessive nutrient loads and poor water quality to affected river systems that resulted in fish kills (Mallin 2000), and phosphorus enrichment of North Carolina waters has been linked to *Pfiesteria* outbreaks (Burkholder *et al.* 1997).

Publicity from these types of events along with the relatively rapid expansion of the hog industry and projections for continued expansion in Manitoba during the 1990s raised concerns about potential negative effects to the environment if manure from this sector was not handled in an appropriate manner. Hog facilities, especially large scale operations, produce a considerable amount of liquid byproduct that is a mixture of hog manure and wash water. This manure slurry is rich in nutrients and disposal of large quantities of manure onto agricultural land without proper management could provide an oversupply of nutrients to the soil profile and create downward leaching into groundwater or transport of excessive nutrients with surface runoff into aquatic systems.

This study was undertaken to obtain a better understanding of hog manure management and some basic information on hog manure applications to land and potential affects to the environment on a field scale because there is a limited amount of this type of data for Manitoba. The South Tobacco Creek area was selected as a site for gathering this data because an infrastructure for collecting some of the data needs was already established. Although the infrastructure for monitoring hog manure applications was not established at the time, it was considered the most cost-effective place to establish such a site for this project.

The main objective of the South Tobacco Creek Manured Watershed Project was to determine water quality characteristics of runoff from fields applied with hog manure (organic fertilizer) and inorganic fertilizer under fertilization practices commonly used by producers and to compare the water quality runoff characteristics between the two fertilizer sources. Water quality characteristics under study included the amount of bacteria, nutrient, organic carbon, and suspended solid residues in runoff that occurred during spring and post-spring rainfall events.

A secondary objective was if possible, to obtain runoff data from a relatively undisturbed natural wooded area and a forage field so water quality characteristics from these areas could be compared with the other fields.

The purpose of this report is to present a summary of the soil and water quality data collected between fall 1997 – spring 2001.

2.0 DESCRIPTION OF STUDY AREA

2.1 General

South Tobacco Creek is located in southern Manitoba, Canada at approximately 98° 20' longitude, 49°21' latitude (Figure 1). South Tobacco Creek has numerous feeder streams in the headwater reach with two main branches, the North Arm and South Arm (Figure 2). Headwater tributaries and the North Arm and South Arm originate along the Manitoba Escarpment. Within the escarpment, elevations of the tributaries change approximately 150 m over 7 km. Riparian zones along stream courses within the escarpment are relatively steep with slopes generally > 10 %. The North Arm and South Arm join to form a single river channel prior to exiting the escarpment approximately 6 km west of Miami, Manitoba (Figure 2). South Tobacco Creek becomes a relatively moderate gradient river between the Manitoba Escarpment and Miami changing approximately 40 m over 5 km. It eventually flows into the Red River via the Morris River. The South Tobacco Creek confluence with the Morris River occurs just north of the Town of Morris.

Soils in the Tobacco Creek Watershed area are generally Orthic Dark Gray Chernozem and Gleyed Dark Gray Chernozem with characteristics that are productive soils for crop production, fairly high water holding capacity, moderate infiltration and limited risk of groundwater impacts from leaching (Michalyna *et al.* 1988, Michalyna 1994, Langman 1986). Surface deposits are characteristic of glacial origins with deep basin deposits of silt, sands, and clays in the lowlands (Weir 1983). Soils transition to coarser near shore sands and gravels on the escarpment upslope. Tills in the escarpment are moderately calcareous primarily derived from Mesozoic shales (Weir 1983).

Mixed broadleaf forest is predominant along riparian corridors of tributary and main river channels within the escarpment. Broadleaf species mainly consist of elm (*Ulmus americana*), burr oak (*Quercus macrocarpa*), maple (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), and aspen (*Populus tremuloides*). The plains below the escarpment are categorized as wooded grassland (Weir 1983). Land use in this area is mainly cropland (Manitoba Land Resource Unit 1997).

2.2 Manured Watershed Study Unit

The Manured Watershed field (MW) occurred on the North Arm of South Tobacco Creek at approximately 98°22'13" longitude, 49°23'55" latitude (NE17-5-7W)(Figure 2). The drainage area for the field was approximately 0.892 ha (2.2 acres) with a slope of about 1.3 % (Appendix 1). Field runoff was sampled at the V-notch weir (site #7, Figure 3). The weir structure captured all surface runoff leaving the MW field. Runoff from the weir entered a small reservoir which in turn initially drains via a municipal ditch for approximately 2 km and then into a tributary feeder stream of the North Arm of South Tobacco Creek. Off-field sampling sites were located upstream (#6) and downstream (#5) of drainage from the small dam reservoir and from field drainage (#8) upstream of the manured field and small dam reservoir (Figure 3).

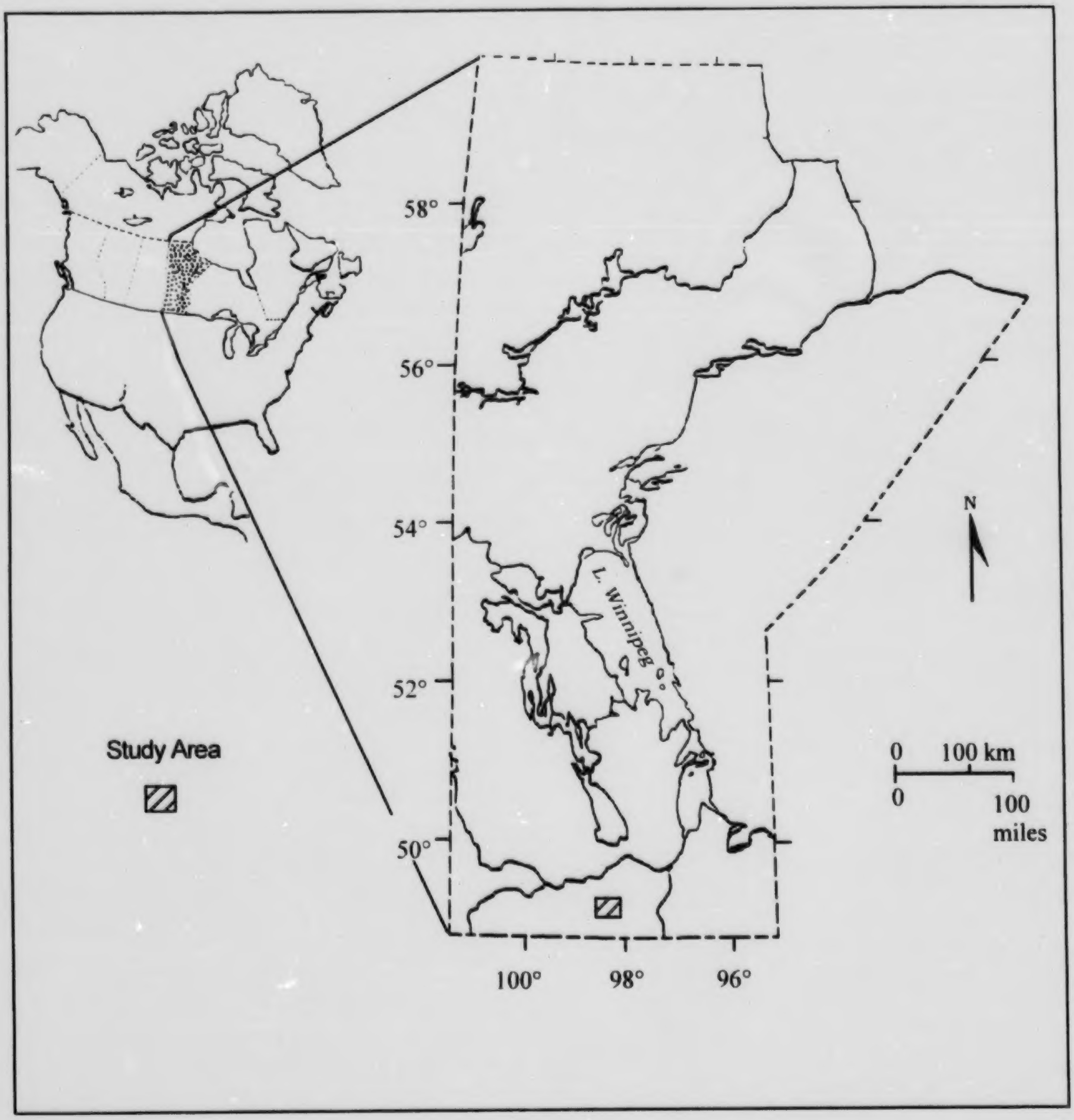

Figure 1. Geographic location of the South Tobacco Creek Watershed in Manitoba, Canada.

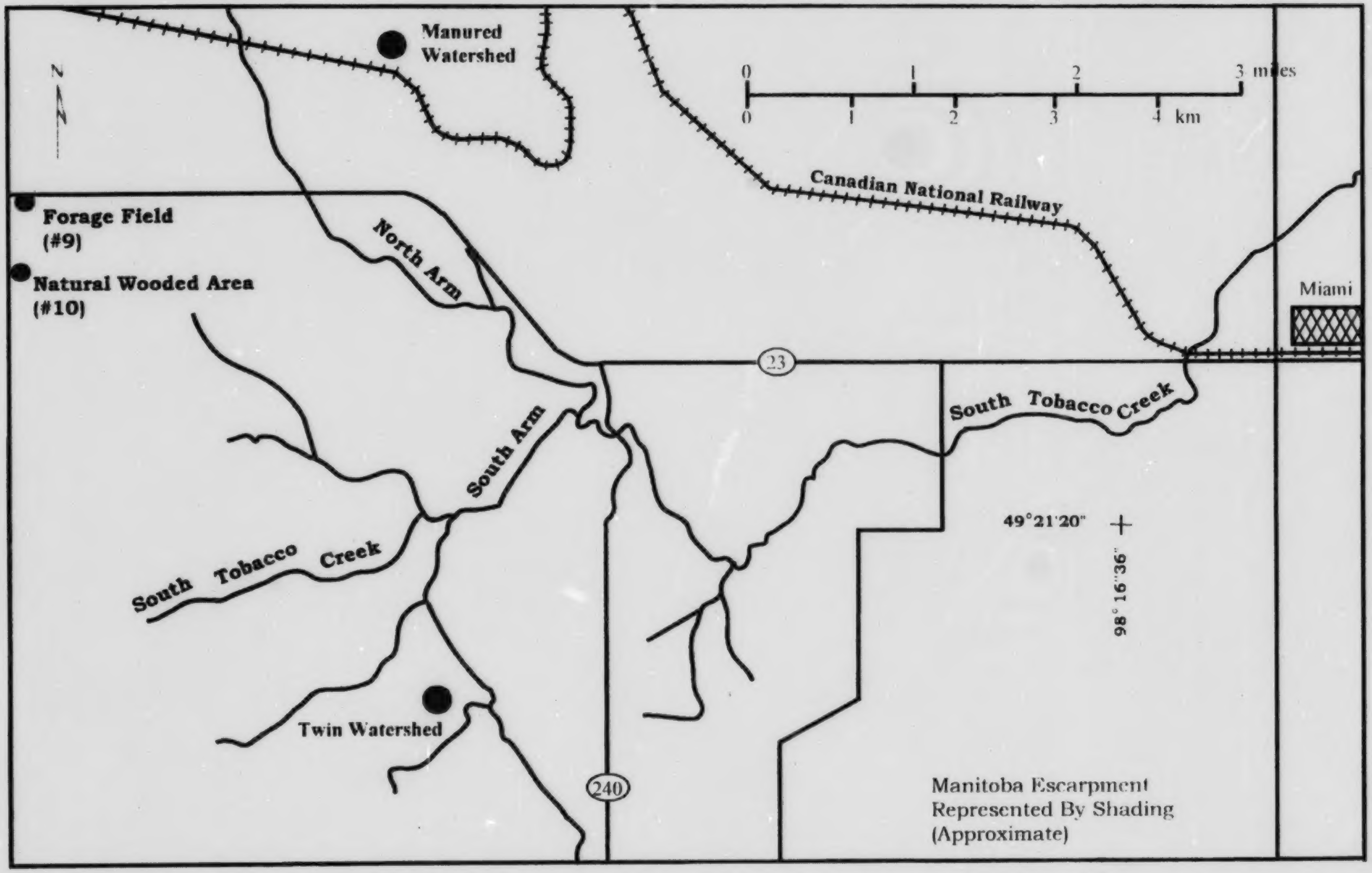

Figure 2. Location of the Natural Wooded Area, Forage Field. Manured Watershed and Twin Watershed study areas within the South Tobacco Creek Watershed, 1998 - 2001.

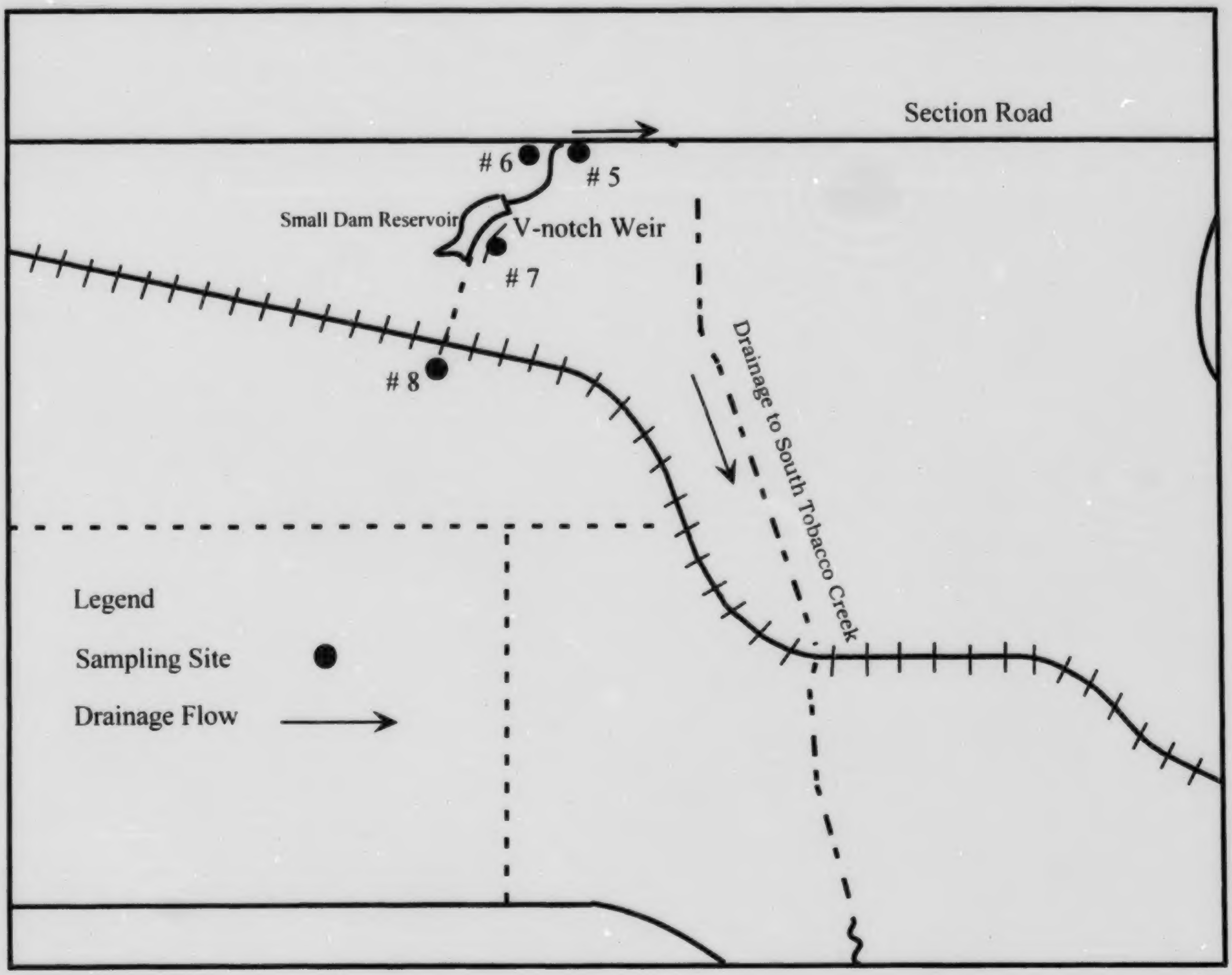

Figure 3. Sampling sites in the Manured Watershed Study Area of the South Tobacco Creek Watershed, 1998 - 2001.

2.3 Twin Watershed Study Unit

The Twin Watershed monitoring site was located on one of the feeder tributaries of the South Arm at approximately 98°21'45" longitude, 49°20'24" latitude (NE29-4-7W)(Figure 2). The study site was separated into two sub-watershed units referred to as the Conventional-till (CT) field (west weir unit) and Zero-till (ZT) field (east weir unit)(Figure 4). The CT and ZT fields were approximately 4.24 ha (10.5 acres) and 5.64 ha (13.9 acres), respectively. Slopes of the fields averaged about 2 % (Appendix 2).

Flows from each of the Twin Watershed study fields joined within approximately 60 m downstream of the weir structures and drained into a small feeder tributary of South Tobacco Creek (Figure 4).

Field runoff sampling sites were located at each V-notch weir (#3 - ZT weir and #4 - CT weir). Off field sampling sites on the receiving tributary were located upstream (#2) and downstream (#1) of the confluence with the drainage channel from the study field units (Figure 4).

2.4 Forage Field

The forage field (FF) monitoring site was located on the western edge of the South Tobacco Creek watershed near Provincial Trunk Highway (PTH) #23 at approximately 98°25'09" longitude, 49°23'03" latitude (NE12-5-8W)(Figure 2). The sub-watershed unit that contained the FF field was approximately 10.1 ha (25 acres). Approximately 7.9 ha (19.5 acres) and 2.2 ha (5.5 acres) was bush and forage land, respectively. The FF was located at the most downstream part of the sub-watershed unit (Appendix 3). The water sample collection site (#9) was located in a natural drainage channel exiting the field and into PTH #23 highway ditch (Appendix 3).

2.5 Natural Wooded Area

The natural wooded area (NWA) monitoring site was about one kilometre south of the FF at approximately 98°25'12"; 49°22'46" (NE12-5-8W)(Figure 2, Appendix 3). The NWA was also a sub-watershed unit of South Tobacco Creek watershed. It was approximately 20.2 ha (50 acres) and was comprised entirely of bush. The water sample collection site (#10) was located in a natural drainage channel exiting the watershed.

3.0 METHODS

3.1 Soil Sampling

3.1.1 Upper Profile

Soil samples were collected from the Manured Watershed and Twin Watershed fields each fall to determine residual nutrient values within the upper 60 cm (2') of soil profile. Hand auger soil sampling equipment was used to collect soil samples to the 60

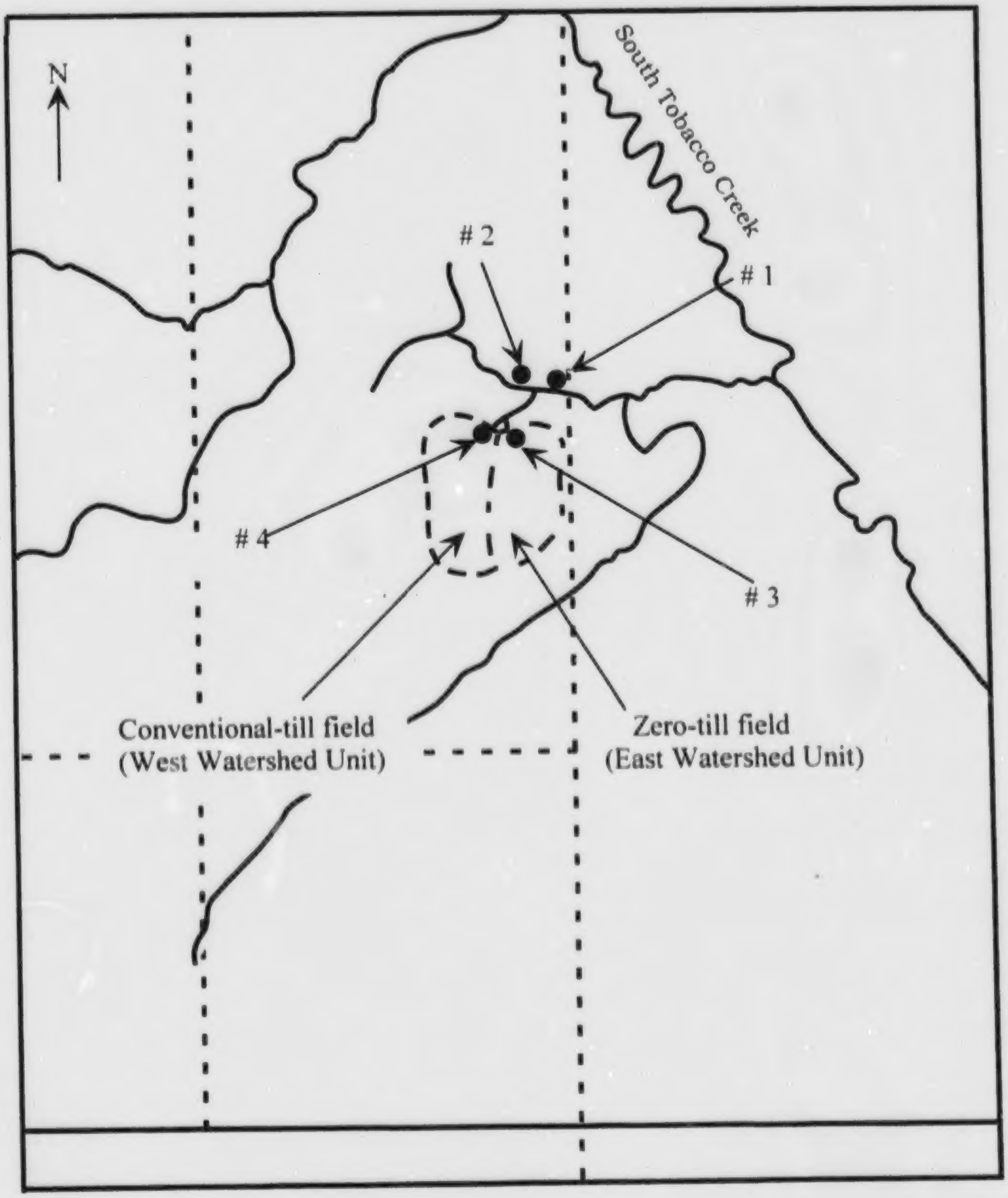

Figure 4. Sampling sites associated with the Twin Watershed Conventional-till and Zero-till field units within the South Tobacco Creek Watershed, 1998 - 2001.

cm depth. Soil samples were collected at 0 - 15 cm (0-6") and 15 - 60 cm (6"- 24") depths. Soil samples were placed in whirl-pac bags, frozen and sent to NorWest Laboratories[3]. Analyses included nitrate nitrogen (nitrate-N), total phosphorus (TP), potassium, sulphate, pH, electrical conductivity, and organic matter content.

Soil samples from the Twin Watershed CT and ZT fields were aggregates of samples from the lower, mid and upper location in each field. For each depth, a soil sample was collected from the different locations and then combined to make an aggregate sample for the field.

Soil samples for the MW field were also collected from an upper, mid and lower area, except there were usually more replicate samples collected at each site. Three soil samples were collected for each depth at each field location. This meant a total of nine samples were collected from each of the targeted depths in the MW field. For each depth, these samples were usually combined to form an aggregate sample, except in the fall of 1997. In 1997, separate soil nutrient analyses was done for each depth from the lower, mid and upper field locations.

3.1.2 Deep Soil Tests

Soil tests to a depth of 305 cm (approximately 10 feet) were conducted in the MW field during the spring of 1998 and 2001. Deep soil tests were collected with a power auger mounted on a half-ton truck. Depths intervals were 0 – 15 cm, 15 – 60 cm, and then intervals of approximately every 30 cm (one foot) to 305 cm. For each depth, approximately three soil samples from different locations in the field were used to form a composite sample.

In 1998, TP was determined to the 60 cm depth while nitrate-N was determined for all depth intervals to 305 cm. During 2001, TP and nitirate-N were both determined for all depth intervals to 305 cm.

3.2 Fertilizer Application

Fertilizer was applied based upon practices used by many producers in Manitoba. Hog manure was applied to the MW field during fall. The manure was applied to the field by broadcast spreading with a low spread diffuser system mounted to a tanker truck. Manure was incorporated into the soil within approximately 48 – 72 hours after application. A deep tiller with harrow attachment was used to incorporate the manure for this study.

Determining the required amount of hog manure was based upon general guidelines available in the document "Farm Practices Guidelines for Hog Producers in Manitoba" (Manitoba Agriculture 1998)[4]. These guidelines provide some generic nitrate-N requirements for different categories of soil conditions as well as some generic conversion factors for nitrogen (N) content in manure.

Soil samples were collected prior to fertilizer application to assist in determining how much manure should be used to supplement soil conditions. This practice, however, is generally considered not to be common for operations under 400 A. U. (animal units)[5] since the Manitoba Manure Management and Mortalities Regulation[6] does not require these operations to conduct soil testing before applying manure to fields. Livestock operations with 400 A. U. or more are required to prepare manure management plans that includes soil testing of N from fields to be spread.

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[3] NorWest Laboratories, 203-545 University Crescent, Winnipeg MB R3T 5S6.

[4] Currently available on Manitoba Agriculture website at http://www.gov.mb.ca/agriculture/livestock/pork/swine/bah00s00.html

Also, there is not a requirement in the Manitoba Manure Management and Mortalities Regulation for any operation to test the N and P content of manure before application. The Farm Practices Guidelines for Hog Producers in Manitoba (Manitoba Agriculture 1998) provides an average and a range of nutrient characteristics for swine manure that can be used for calculating an estimated amount needed for fertilization purposes. The range is relatively large so in some years a sample of the liquid hog manure was collected and analyzed for ammonia-N content with an "Agros Nitrogen Meter" in the field prior to application. An estimate for the amount of hog manure needed assumed ammonia-N comprised most of the TN. An estimated amount of hog manure (imperial gallons acre^{-1}) was applied to supplement residual nitrogen values in the soil to values considered needed for the intended crop the following spring. For the purposes of this study, a composite sample of hog manure was obtained to determine a more accurate measurement of nutrients in the applied manure and rate of fertilization. Manure samples were collected from each application by placing three one-gallon pails across the spread pattern width. A relatively even quantity from each pail was added to form the composite sample. This sample was sent to NorWest Laboratories to determine N and P content of the manure applied to the MW field.

Inorganic fertilizer was used on the Twin Watershed CT and ZT fields. Fertilizer was usually applied to these fields during seeding in spring. The amount of fertilizer added to fields was based upon the residual nitrate-N and TP content from soil sample analyses done the previous fall and what additional amount was needed for the crop being seeded. Two exceptions to spring application occurred. Approximately 67 kg ha^{-1} (60 lb acre^{-1}) of anhydrous ammonia nitrogen was applied to the CT field in the fall of 1998 and 1999.

3.3 Water Sampling Equipment

A double angle V-notch plywood weir was constructed at the drainage outlet of each Twin Watershed field unit to accommodate a wide range of runoff water flows. The lower 90° angle V-notch was capable of passing flows of less than 0.20 m^3 s^{-1}, while the 120° angle V-notch could accommodate larger flows. Twin Watershed weirs could pass a total flow of approximately 0.84 m^3 s^{-1} before being overtopped (Yarotski undated). Due to lower projected flows, only a 90° angle V-notch weir was used at the Manured Watershed site. All runoff water leaving a field was captured and directed past the automated water sampler sensor tube located adjacent to the V-notch weir.

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[5] An animal unit equates to the number of animals it takes to produce 73 kg of total nitrogen in a 12 month period. For example, one dairy cow, one beef cow, one hog sow (farrow to finish) and one roaster chicken are equivalent to 2.0, 1.25, 1.25, and 0.01 A. U., respectively.

[6] Livestock Manure and Mortalities Management Regulation, Manitoba Regulation 42/98 under the Manitoba Environment Act.

Automated sampling equipment at each weir consisted of an ultrasonic sonar depth sensor (Campbell Scientific) linked to a data logger (Campbell Scientific CR10), an automated water-sampling instrument (Sigma Scientific 900) and solar power with battery power backup. The automated samplers collected water samples and recorded water depth and time data that permitted the calculation of flow volumes. Rainfall monitoring devices (Texas Electronics Tipping Bucket) were installed at each site to provide estimates of rainfall amounts. Snow depth measurements were usually taken three times during winter (January, February, and March). Water equivalency data was determined from snow samples to estimate the water volume of snow cover on each site. The last snow survey prior to spring thaw was used to determine final water equivalency data for spring runoff conditions.

Water samples were collected at weirs when flow volumes activated automated sampling devices. The automated samplers were checked a minimum of once per day during the runoff period. During peak runoff periods, water samples were sometimes collected between 2 – 3 times per day. The automated samplers were not always reliable for collecting water samples during periods of very low runoff flows. Grab samples were also collected at these times. Water samples were stored in coolers and kept cool with ice packs or refrigerated until shipped to the laboratory.

3.4 Water Sample and Data Analyses

Water samples from the Twin Watershed and Manured Watershed weir locations and the NWA were sent to the Environment Canada laboratory[7] in Saskatoon to be analyzed for suspended solids, carbon and nutrients. Fecal coliform bacteriological samples were collected as grab samples when the automated samplers were being checked. These samples were sent to Enviro-Test Laboratories[8] in Winnipeg for analyses. Water samples collected from the FF and sampling sites on the receiving drains and water courses of the Twin Watershed and Manured Watershed weirs were also sent to Enviro-Test laboratories for analyses of suspended solids, carbon and nutrients.

Statistical differences ($p \leq 0.05$) in mean values between sites and mean values between years for each site were determined by Analyses of Variance (ANOVA). Probability plots indicated that a $\log_{10}$ transformation of the data provided the best means for stabilizing the variances to increase data normality. ANOVA was done on transformed data. Since each comparison usually only involved 3 – 5 mean values, Bonferroni pairwise comparison of means was used to identify which means were significantly different. Systat v7.0 statistical program was used for the statistical procedures.

Annual estimates for total loads of nutrients transported off-field with spring and post-spring runoff periods were based upon the sum of the products of daily mean nutrient concentrations multiplied by daily mean runoff volume. Water quality data was not available for all days that runoff occurred and nutrient concentrations from days with data were used as substitutes for determining missing estimates. For example, if water quality data was not available on the first or last day of sampling, the nutrient concentration from the following or previous day was used to calculate the estimate. An average of the nutrient concentration between the preceding and following day was used for the remaining situations with missing data.

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[7] Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon, SK S7N 3H5.

[8] Enviro-Test Laboratories, 745 Logan Avenue, Winnipeg, MB R3E 3L5.

There were no water quality data collected from the NWA during 1998 so values shown on graphs actually represent a mean value for data collected from this area between 1995 – 1997.

Water quality and soil nutrient data values that were reported at laboratory detection limits (*e.g.*, < 5 mg L^{-1}) were assumed to be at that value (5 mg L^{-1}) for calculation purposes. This was a more conservative approach and provided slightly higher calculated values than if the actual concentration was known.

The "~" symbol is used with values in parenthesis throughout the report to indicate these values are approximate and represent values from Appendices that may have been rounded to the nearest decimal or integer value.

4.0 RESULTS AND DISCUSSION

4.1 Soil Testing

4.1.1 Upper Profile

Annual mean soil test results for each field are given in Appendix 4. Green and Turner (1999) showed individual mean nutrient values from the lower, mid and upper field locations of the Manured Watershed field (MW) for the fall of 1997.

Residual nutrient values in fall soil tests of the MW field were consistently higher than Twin Watershed fields. Fall soil nitrate-N values for the MW field ranged from 28 – 84 kg ha^{-1} at 0 – 15 cm (0 – 6") and 48 – 317 kg ha^{-1} at the 0 – 60 cm depth (0- 2')(Figure 5b). In comparison, nitrate-N values for Twin Watershed fields only ranged from about 1 – 12 kg ha^{-1} at the 0 – 15 cm depth, and were usually less than 25 kg ha^{-1} from 0 – 60 cm deep (Figure 5). Fluctuations of nitrate-N values between years were usually greater for the MW field because soil N values were much higher than what occurred on the Twin Watershed non-manured fields.

The high N values in the 1997 fall soil samples of the MW field were unexpected. Soil sample analyses was not available at the time of the initial manure application, which is a condition that can occur for any operator who does not regularly test soils before manure applications. At that time it was considered that there could be about 45 kg ha^{-1} of residual soil N based upon a general assumption from past experience of producers in the area. Manure was applied to add approximately another 60 kg ha^{-1} of available N for the following spring. This assumption seemed reasonable at the time because of the land use practice for this field in previous years. However, this assumption was well underestimated. Green and Turner (1999) noted the high values in the fall of 1997, but could not fully explain why the values were so high.

The field was originally part of an old farmyard. It had been under bush and had not been a heavily utilized confined livestock area. Alfalfa was grown on the site from 1992 – 1995 with no fertilizer applications during those years. A manure application of approximately 34,000 L ha (3000 gal $acre^{-1}$) was applied to fallow in the summer of 1996

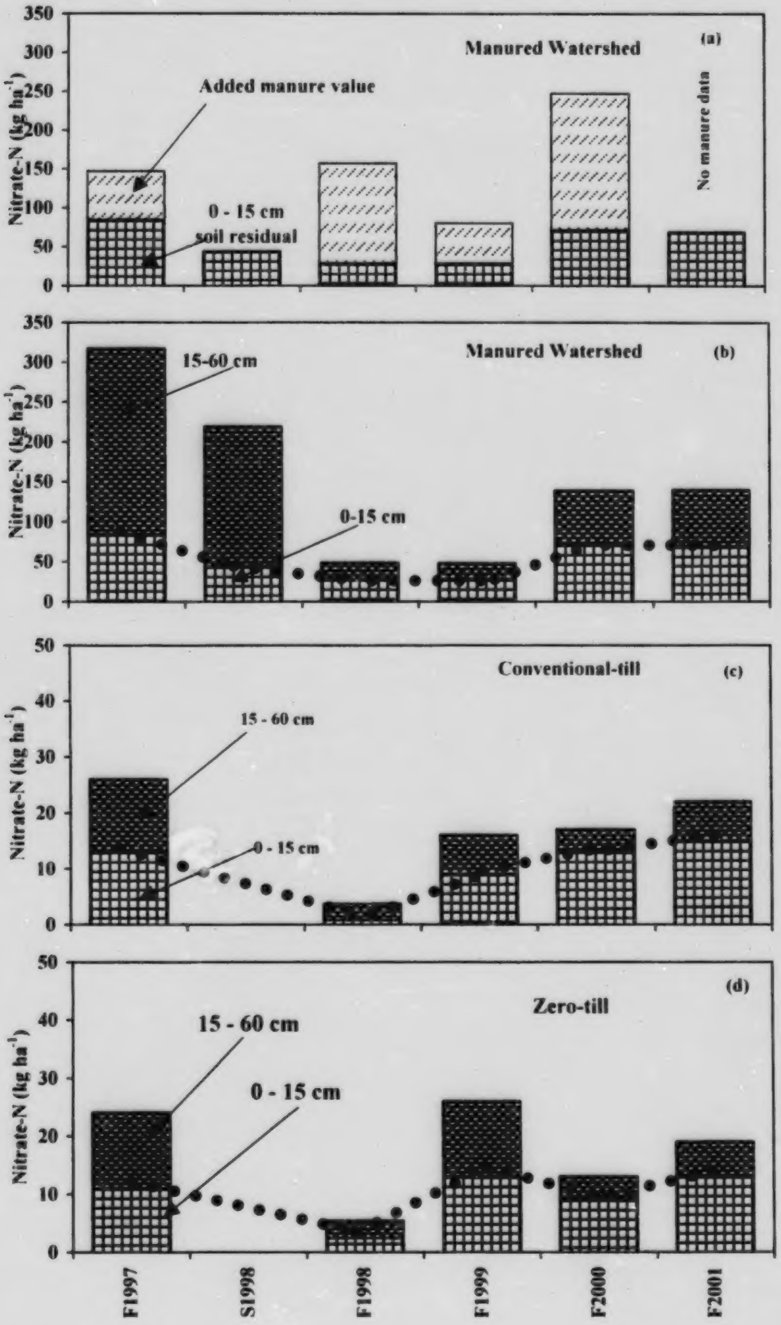

Figure 5. Mean nitrate-N values (kg ha^{-1}) for soil samples from the Manured Watershed, Conventional-till and Zero-till fields in the South Tobacco Creek Watershed , 1997 – 2001.

Note: Figure 5a shows nitrate-N values at 0 - 15 cm plus manure added value. Figures 5b, c and d shows soil nitrate-N values at both 0 - 15 and 15 - 60 cm depths. Dotted lines show variation of nitrate-N values for the 0 - 15 cm depth during fall.

F1999 = Fall 1999; S1998 = Spring 1998, etc.

and barley planted in 1997. It was not considered this amount of manure alone would cause such high nitrate-N values in the soil, especially after a barley crop with a good yield (approximately 80 bushels acre^{-1}). It was suspected that tillage of the previous alfalfa crop could have released a significant amount of N since decomposition of ploughed alfalfa stands can lead to increased nitrate-N levels (Campbell *et al.* 1994, Philipps and Stopes 1995). Contributions up to 115 kg N ha^{-1} occurred after an alfalfa stand was intentionally desiccated in southwestern Michigan (Rasse and Smucker 1999). Fox and Piekielek (1988) calculated a N replacement value from a three year old alfalfa stand to the following corn crop was approximately 136, 36 and 16 kg N ha^{-1} in the first, second, and third corn crop year, respectively. The manure application in 1996 may have provided an excess amount not needed by the 1997 barley crop and allowed for a greater residual carry-over into the fall.

Green and Turner (1999) had also identified some uncertainty with the accuracy of the 1997 soil tests from the MW field. There were some problems with submission of these samples to the laboratory and it was not known how this affected the final analyses. Subsequent soil testing in the spring of 1998 appeared to indicate the 1997 fall test results may not have been quite as high as the fall laboratory analyses indicated. However, the spring values were still much higher than expected which led Green and Turner (1999) to conclude fall nitrate-N soil values in the MW field probably were not too much lower than originally reported. The spring values were also still very high relative to the Twin Watershed fields (Appendix 4).

Total phosphorus values for the MW field also showed higher values than from either Twin Watershed field. Values in the upper 15 cm of soil for the MW field ranged from 73 kg ha^{-1} to 134 kg ha^{-1} between the fall of 1997 to the fall of 2001 (Figure 6a). As with N, TP values for the Twin Watershed fields were considerably lower. Total phosphorus values in the top 15 cm ranged between 16 – 29 kg ha^{-1} for the CT field and 24 – 47 kg ha^{-1} for the ZT field (Figure 6c and d). Higher values were expected in the MW field since P occurs in hog manure and it would be automatically added to soil as hog manure was spread to meet N requirements. When considering N requirements, most manure fertilizer used in Nebraska contained proportionally more P than the crop needed (Schepers and Francis 1998). Novak *et al.* (2000) found application of hog manure at atypically high N rates resulted in high P build up in soils in a Middle Coastal Plain region of North Carolina. At the Glenlea Research Station in Manitoba during 1976 – 1978, Tokarz *et al.* (1979) observed relatively high applications of hog manure (250 kg N ha^{-1} and 500 kg N ha^{-1}) provided high available-P concentrations in the soil surface in the third year of study compared to the first year. Interestingly, they also found that application of P to the control plot at 25 kg P ha^{-1} with a commercial fertilizer for barley and wheat crops was also showing some P accumulation on the soil surface. Simard *et al.* (2001) noted that long term application of manure could cause P in soil to accumulate up to saturation levels for soil-P.

Figure 6b shows that consecutive annual applications of hog manure to the same field appeared to be causing a gradual accumulation of TP in the 0 – 15 cm depth and this reflected through to the 0 – 60 cm depth. A similar consistent annual trend was not as apparent in the Twin Watershed CT or ZT fields (Figure 6c and d). Although more hog manure was applied to the MW field in some years than needed to meet estimated N

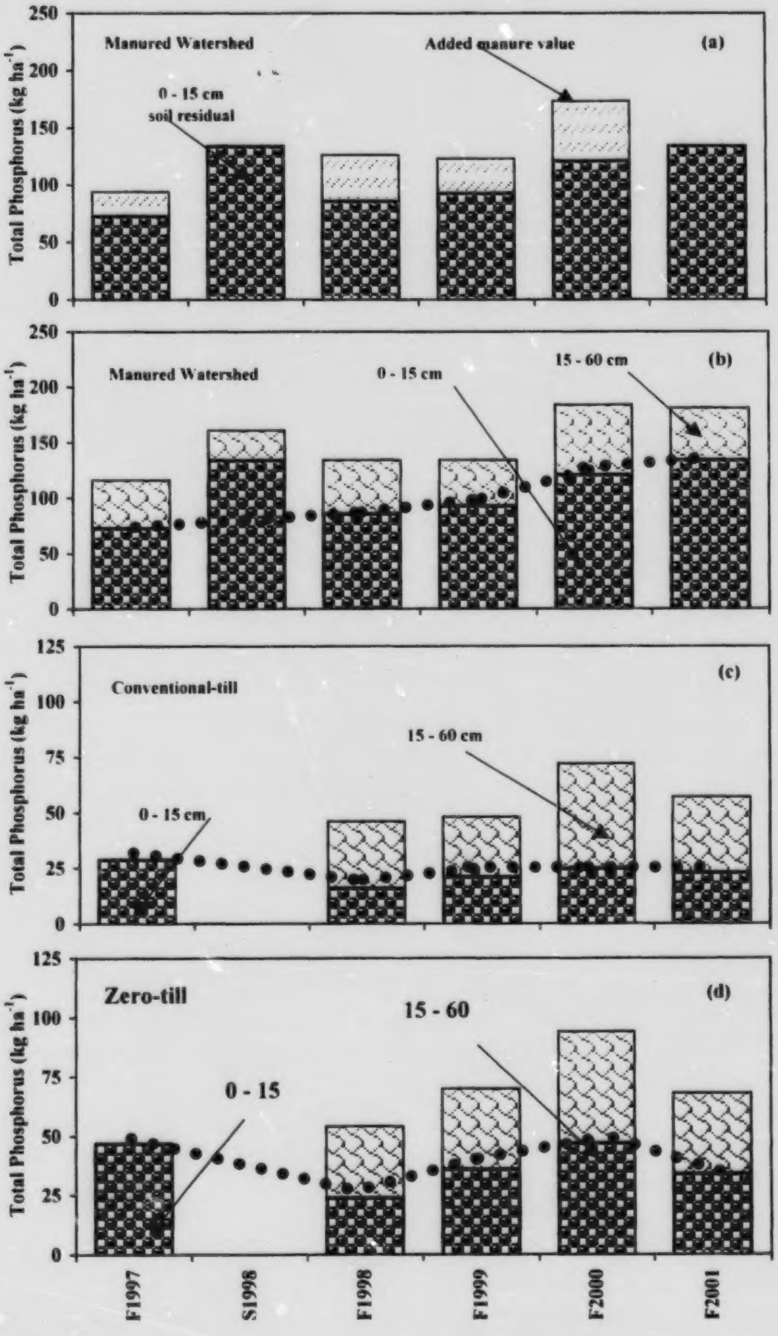

Figure 6. Mean total phosphorus values (kg ha^{-1}) for soil samples from the Manure Watershed, Conventional-till and Zero-till fields in the South Tobacco Creek Watershed , 1997 – 2001.

Note: Figure 6a shows phosphorus values at 0 - 15 cm plus manure added value. Figures 6b, c and d shows soil phosphorus values at both 0 - 15 and 15 - 60 cm depths. Dotted lines show variation of phosphorus values for the 0 - 15 cm depth during fall.
F1999 = Fall 1999; S1998 = Spring 1998, etc.

requirements during this study, P build up in the soil from repeated manure applications is likely to occur when manure is applied solely based upon crop N needs.

Rotation of land receiving manure applications probably already occurs for many operations in Manitoba and this would undoubtedly help reduce the opportunity for P accumulation. Testing for P as well as N, especially in areas where hog manure is applied to the same land parcels on a consecutive and frequent basis, would help determine if residual soil P values were accumulating beyond crop requirements. However, as Schepers and Francis (1998) noted, applications of manure based upon P instead of N requirements usually required a higher level of management due to the need for use of supplemental inorganic N.

4.1.2 Deep Soil Tests

One of the concerns with additions of fertilizers to soils is the possibility of over fertilization and subsequent nitrate-N contamination of the ground water. This has especially been a concern with the spreading of hog manure because it usually requires more management than inorganic fertilizers. Utilizing hog manure effectively as a fertilizer is made more demanding by variability that can occur in manure nutrient characteristics and the difficulties with accurately determining how quickly organic N will be mineralized into an available inorganic form. There is also a need to spread hog manure within a certain time interval otherwise storage capacity will be exceeded. Unlike hog manure, a known formulation for a specified amount of inorganic fertilizers can be obtained only when needed.

Consecutive annual applications of hog manure to the MW field over a four year period indicated there was downward movement of nitrate-N at all depths to 305 cm (10 feet) except between the 15 – 91 cm depth (Figure 7). Increases to the deeper depths in 2001 were considered to have mainly originated from the high values observed in the 15 – 91 cm depth during 1998, but increases also appeared to have come from sources in other years. Nitrate-N within 15 – 91 cm during spring 1998 was approximately 153 kg ha^{-1} more than during spring 2001, yet the total gain of nitrate-N from 91 – 305 cm in spring 2001 was approximately 282 kg ha^{-1} (Figure 7). Nitrate-N leaching in ground water has been related to N fertilization rate (Pang *et al.* 1998, Owens *et al.* 1994) with movement and accumulation dependent upon climatic conditions, soil properties, crop cover and fertilization/soil management practices (Sainju *et al.* 1999, Pang *et al.* 1998).

Phosphorus generally did not appear to be moving to deeper depths at the same relative rate as N but there was evidence of some downward movement. The greatest accumulation of TP was in the upper 60 cm where values ranged from approximately 56 kg ha^{-1} at 15 – 60 cm to over 150 kg ha^{-1} in the top 15 cm of soil (Figure 8). Phosphorus is generally adsorbed to soil particles more readily and is usually not as mobile in soil as N, especially for soils with a higher clay content. Excessive animal manure applications have been attributed to P movement to depths below 60 cm in sandier Coastal Plain soils (Novak *et al.* 2000, Eghball *et al.* 1996, Mozaffari and Sims 1994). Repeated heavy applications of poultry wastes substantially reduced P sorption capacity in Oklahoma top-soils allowing for greater downward P movement (Sharpley *et al.* 1993). Phosphorus leaching below the 150 cm depth was deemed possible with applications of feedlot cattle manure in Alberta continuing beyond 16 years (Whalen and Chang 2001). Comfort and

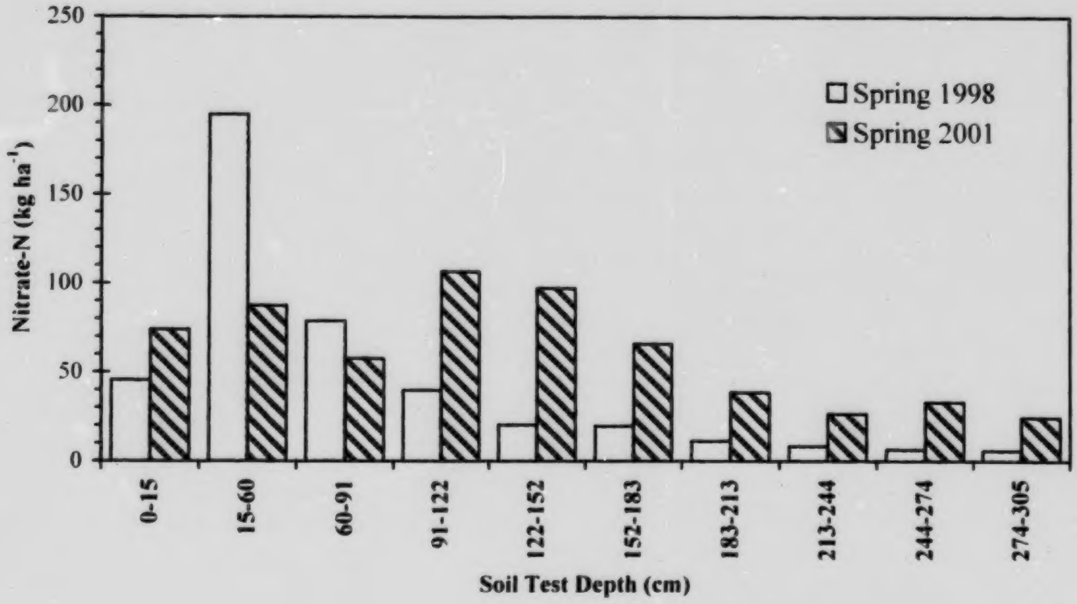

Figure 7. Nitrate-N values (kg ha^{-1}) for soil test profiles between surface to the 305 cm depth from the Manured Watershed field, May 1998 and May 2001.

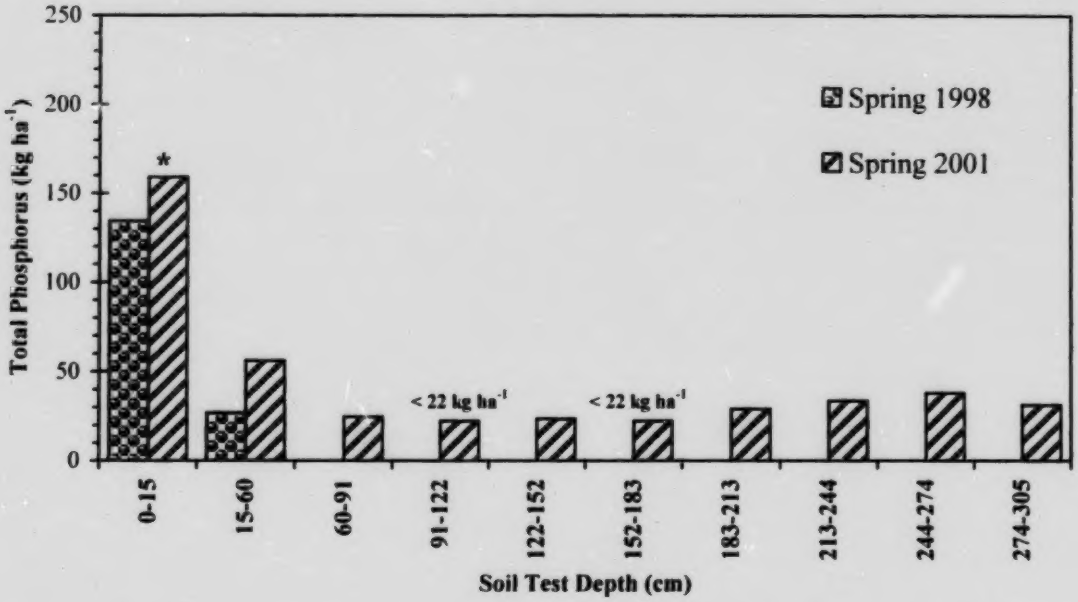

Figure 8. Total phosphorus values (kg ha^{-1}) for soil test profiles between surface to the 305 cm depth from the Manured Watershed field, May 1998 and May 2001.

*** = Used fall 2000 soil value and added the applied manure value since there appeared to be a problem with spring soil test 2001 values at the 0 - 15 cm depth.**

Note: There was no phosphorus data for depths 60 - 305 cm during 1998. Histogram bars with < 22 kg ha^{-1} indicate all samples at that depth were less than laboratory detection limits. All other depths had at least one or two of the three samples above detection limits.

Eghball (1996) noted research in Nebraska showed that under some circumstances manure derived P can leach lower into the soil profile than inorganic fertilizer P. They considered organic materials associated with manure could have inhibited calcium phosphates from precipitating.

The limited data in this study indicated greater downward movement of P in soil occurred than might be expected given application rates were generally not as high as reported in studies from the Eastern States. However, it should be noted that results in this study were based upon a small number of samples. As well, any soil-P values reported as less than the laboratory detection limit (< 5 mg Kg^{-1}) were assumed to be 5 mg Kg^{-1} for calculation purposes so values for some of the deeper depths in Figure 8 would be somewhat higher than the actual condition. Based upon conditions experienced elsewhere, and despite the data from this study being rather limited, it would appear beneficial for land receiving frequent applications of hog manure to have some deep soil testing done for N and P on a periodic time frame such as every five years. This type of sampling would help ensure manure applications are not causing accumulations at depth and reduce the potential for leaching into ground water sources.

4.1.3 Manure Tests

Analyses of manure samples indicated that the TN content was relatively similar for the first two years of the study with the greatest range in values occurring for the last two years. Total nitrogen content during 1997 and 1998 was approximately 2.0 kg 1000 L^{-1} of manure (Table 1, Figure 9). A manure sample from this operation during 1995 also showed values similar to those in 1997 and 1998. The concentration of TN during 1999 (~ 1.2 kg 1000 L^{-1}) was only about 50 – 60 % of the values for the previous two years and then it was more than double (~ 4.8 kg 1000 L^{-1}) in 2000 (Table 1, Figure 9). Ammonia-N comprised the majority of TN in all years and ranged from 54 % to 88 % of TN between 1997 – 1999.

The P content of hog manure appeared to be more consistent. Concentrations between 1995 to 1999 ranged from 0.4 – 0.5 kg 1000 L^{-1}. Similar to N, TP for the manure sample during 2000 (~ 1.1 kg 1000 L^{-1}) was about double the values for the other years (Figure 9, Table 1).

There are currently no regulatory requirements in Manitoba to have manure analyzed before applications to land. Guidelines for hog producers in Manitoba (Manitoba Agriculture 1998) provide a basis for using estimates of nutrient content in manure (Table 4 in the guidelines), but estimates based upon these values can vary substantially depending upon which value is chosen. For example, assuming a) 5000 imperial gallons $acre^{-1}$ (~ 56,000 L ha^{-1}) of hog manure are applied to land, b) 30% of the organic-N is mineralized in the first year, and c) about 20 % of the ammonia-N in manure is volatilized to air, an estimated amount of available N ranges between 5.6 – 260.0 kg ha^{-1} (~ 5.0 – 232.0 lbs $acre^{-1}$). It is suggested in the guidelines that values in Table 4 of the document be used as a last resort and refer to a Manitoba Agriculture fact sheet[9]

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[9] Manure Management Facts – Manure as a Resource – Agronomic Value of Manure. Canada-Manitoba Agreement on Agricultural Sustainability.

Table 1. Chemical characteristics (kg 1000 L^{-1}) and quantity of liguid hog manure applied ($L\ ha^{-1}$) to the Manured Watershed field during fall, 1997 - 2000.

Variable		1995	1997	1998	1999	2000
		(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**
Total Nitrogen		1.80 **[18.0]**	1.95 **[19.5]**	2.30 **[23.0]**	1.20 **[12.0]**	4.80 **[48.1]**
Ammonia-N		1.43 **[14.3]**	1.27 **[12.7]**	2.03 **[20.3]**	0.65 **[6.5]**	ND
Total Organic Nitrogen		0.37 **[3.7]**	0.68 **[6.8]**	0.27 **[2.7]**	0.55 **[5.5]**	ND
Phosphorus		0.47 **[4.7]**	0.41 **[4.1]**	0.53 **[5.3]**	0.40 **[4.0]**	1.06 **[10.6]**
Potassium		0.73 **[7.3]**	0.77 **[7.7]**	0.88 **[8.8]**	0.46 **[4.6]**	1.52 **[15.2]**
Sulphur		0.11 **[1.1]**	0.08 **[0.8]**	0.09 **[0.9]**	0.06 **[0.6]**	ND
Calcium		0.28 **[2.8]**	0.40 **[4.0]**	0.30 **[3.0]**	0.25 **[2.5]**	ND
Magnesium		0.21 **[2.1]**	0.16 **[1.6]**	0.17 **[1.7]**	0.17 **[1.7]**	ND
Sodium		0.14 **[1.4]**	0.17 **[1.7]**	0.13 **[1.3]**	0.08 **[0.8]**	0.30 **[3.0]**
pH	Units	7.1	7.1	7.1	6.8	ND
Conductivity	(uS cm^{-1})	9.4	9.4	12.6	7.0	ND
Moisture	%	98.5	98.5	98.5	98.7	ND
Quantity	L ha^{-1}	ND	**51630**	**76000**	**76800**	**49000**
Applied	[gal $acre^{-1}$]	ND	4600	6764	6842	4365

ND = No data.

Note: original laboratory results or field measurements not shaded and gallons refer to imperial gallons.

Shaded identifies conversion to alternative measurements provided for convenience. These conversions may not be precise because of rounding.

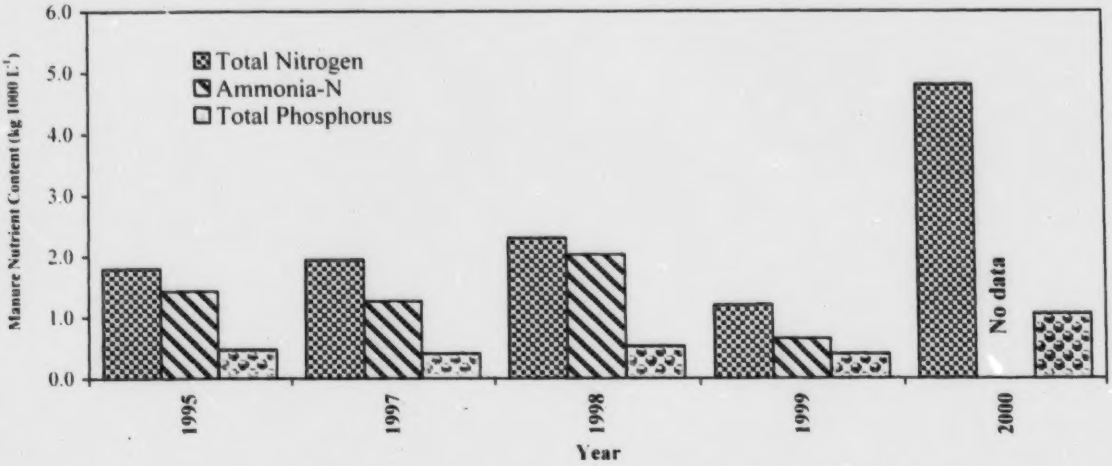

Figure 9. Concentrations of total nitrogen, ammonia-N, and total phosphorus in liquid hog manure applied to the Manured Watershed field during fall, 1997 – 2000.

Table 1. Chemical characteristics (kg 1000 L^{-1}) and quantity of liguid hog manure applied ($L\ ha^{-1}$) to the Manured Watershed field during fall, 1997 - 2000.

Variable		1995	1997	1998	1999	2000
		(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**	(kg 1000 L^{-1}) **[lbs 1000 gal^{-1}]**
Total Nitrogen		1.80 **[18.0]**	1.95 **[19.5]**	2.30 **[23.0]**	1.20 **[12.0]**	4.80 **[48.1]**
Ammonia-N		1.43 **[14.3]**	1.27 **[12.7]**	2.03 **[20.3]**	0.65 **[6.5]**	ND
Total Organic Nitrogen		0.37 **[3.7]**	0.68 **[6.8]**	0.27 **[2.7]**	0.55 **[5.5]**	ND
Phosphorus		0.47 **[4.7]**	0.41 **[4.1]**	0.53 **[5.3]**	0.40 **[4.0]**	1.06 **[10.6]**
Potassium		0.73 **[7.3]**	0.77 **[7.7]**	0.88 **[8.8]**	0.46 **[4.6]**	1.52 **[15.2]**
Sulphur		0.11 **[1.1]**	0.08 **[0.8]**	0.09 **[0.9]**	0.06 **[0.6]**	ND
Calcium		0.28 **[2.8]**	0.40 **[4.0]**	0.30 **[3.0]**	0.25 **[2.5]**	ND
Magnesium		0.21 **[2.1]**	0.16 **[1.6]**	0.17 **[1.7]**	0.17 **[1.7]**	ND
Sodium		0.14 **[1.4]**	0.17 **[1.7]**	0.13 **[1.3]**	0.08 **[0.8]**	0.30 **[3.0]**
pH	Units	7.1	7.1	7.1	6.8	ND
Conductivity	(uS cm^{-1})	9.4	9.4	12.6	7.0	ND
Moisture	%	98.5	98.5	98.5	98.7	ND
Quantity Applied	L ha^{-1} [gal $acre^{-1}$]	ND ND	**51630** 4600	**76000** 6764	**76800** 6842	**49000** 4365

ND = No data.

Note: original laboratory results or field measurements not shaded and gallons refer to imperial gallons.

Shaded identifies conversion to alternative measurements provided for convenience. These conversions may not be precise because of rounding.

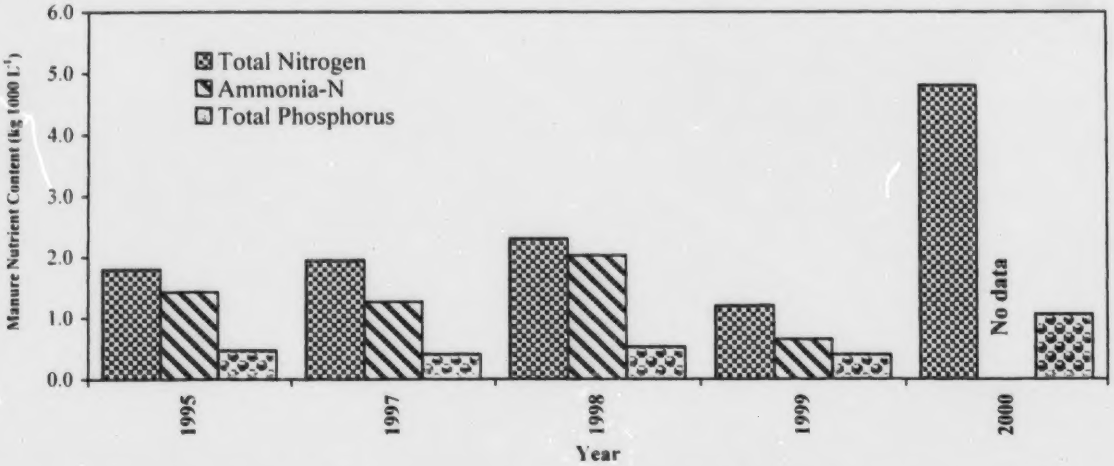

Figure 9. Concentrations of total nitrogen, ammonia-N, and total phosphorus in liquid hog manure applied to the Manured Watershed field during fall, 1997 – 2000.

entitled "Manure as a Resource" for better estimates. Even so, estimates based upon the minimum and maximum N values from this fact sheet can still vary between 86.0 – 112.0 kg ha (~ 77.0 – 100.0 lbs acre^{-1}) with the assumptions from the previous example. Variations in factors such as the amount of ammonia-N volatilization and mineralization of organic-N can create numerous additional combinations for determining estimates.

It is generally considered that variation of nutrient content in manure from a hog operation will remain within a reasonably consistent range as long as there are no major changes to the operation such as using different feed mixtures or the type of stock raised. Manure analyses for the first two years of this study (1997 – 1998) and for a previous sample collected from the same hog manure supply in 1995 tended to support this concept, while the 1999 and 2000 results did not. Any number of factors could have caused variations in manure nutrient content for the latter two years. Since there were no major changes to the hog operation over the course of this study, the variability could have occurred during application. For example, incomplete agitation of the manure in the storage cell would not provide a uniform mix prior to conveyance to fields. If manure applied to this field in 2000 came from the bottom of a storage cell that was not fully agitated, it could cause higher concentrations of nutrients associated with particulate matter such as phosphorus and organic nitrogen than in other years where agitation was more complete.

The difference between the mean values of nutrient content in manure for this study and the range and mean values provided by guidelines indicated that testing of manure from each hog operation to establish the nutrient content that could be reasonably expected from the manure storage facility would be beneficial. Because of the variability that can occur due to a variety of factors, tests over a series of years would also provide a better estimate for the expected variability from an operation. The nitrogen content of manure in this study was actually lower than mean values suggested in guidelines. If manure was applied based upon the mean guideline value, an under application of N could occur. Soil testing for any land that receives hog manure would also appear beneficial, especially if the land is receiving annual or multiple manure applications because there are several factors in manure management that can affect the amount of nutrients applied to land (*e.g.*, ammonia volatilization, environmental conditions affecting mineralization, proper agitation of manure while emptying storage, etc.).

4.2 Hydrology

Detailed hydrographs illustrating runoff flows from the Manured Watershed and Twin Watershed fields between 1998 - 2001 spring and summer runoff events as well as meteorological information are provided in Prairie Farm Rehabilitation Administration (PFRA) annual reports (Yarotski and Miller 1999, 2000, 2001, 2002). Summaries of daily runoff volumes and nutrient load estimates from annual spring runoff periods and from post-spring runoff events are provided in Appendices 5a-5f.

4.2.1 Spring Runoff

Spring runoff was fairly variable between years. The greatest runoff volume (~ 428 m^3) from the MW occurred during 1998 (Table 2). There was only two days of runoff during 1999 (~ 8 m^3) that was a fraction of what occurred in 1998. Runoff was not much greater the following years. There was no measurable runoff from the MW field during 2000. Similar to 1999, a very small amount (~ 26 m^3) occurred in 2001 (Table 2). Any spring runoff from the MW field usually only lasted a couple of days (Appendices 5a, 5b, 5d and 5f).

Runoff volumes from the Twin Watershed CT and ZT fields were considerably larger due to the larger sizes of these fields (4.24 ha – 5.64 ha) compared to the MW field (0.89 ha). The ZT field was also slightly larger than the CT field so total runoff from this field was consistently greater than from the CT field. Total spring runoff volume from the ZT field during 1998, 1999, 2000 and 2001 was approximately 4400 m^3, 2600 m^3, 1900 m^3 and 3300 m^3, respectively. In comparison, total spring runoff from the CT field for 1998, 1999, 2000 and 2001 was approximately 3200 m^3, 750 m^3, not measurable, and 2800 m^3, respectively (Table 2). Even when considering unit area runoff volumes (m^3 ha^{-1}), the ZT field usually had the highest amount of runoff compared to the CT or MW fields (Table 2). During spring, runoff events from the ZT and CT fields could occur over a period of three to four weeks, although the majority of runoff volume generally occurred on consecutive days within a one-week period (Appendices 5a, 5b, 5d and 5f).

Table 2. Annual runoff volume (m^3) and unit area runoff volumes (m^3 ha^{-1}) from Manured Watershed, Conventional-till and Zero-till fields during spring runoff and post-spring runoff periods, 1998 – 2001.

Year	Spring Runoff m^3 (m^3 ha^{-1})			Post-Spring Runoff m^3 (m^3 ha^{-1})		
	MW Field	CT Field	ZT Field	MW Field	CT Field	ZT Filed
1998	428 (481)	3200 (755)	4400 (780)	NR	NR	NR
1999	8 (9)	750 (177)	2600 (461)	NR	133 (31)	274 (48)
2000	NR	NR	1900 (337)	NR	158 (37)	295 (52)
2001	26 (29)	2800 (660)	3300 (585)	NM	NM	NM

NR = Negligible runoff and not measurable.

NM = Not monitored.

Values from Appendices that were < 100 m^3 rounded to nearest integer and those > 1000 m^3 rounded to nearest hundredth m^3.

Note: To convert m^3 to acre-feet multiply by (8.106×10^{-4}). One acre-foot = 1,233 m^3.

Runoff volume is not only dependent upon the size of an area but is also largely influenced by the amount of winter snowfall and other climatic factors such as temperature warming rate and spring precipitation events. More gradual temperature warming may produce less runoff volume for the same amount of snow-pack from one year to the next where greater wind assisted evaporation loss occurs or a longer, slower melt allows greater ground absorption due to ground thaw. Also, snow density and water equivalency of the snow pack will determine how much water is generated from different snow packs.

Snow surveys conducted each winter showed that the greatest runoff volumes from the three fields occurred during spring 1998 where there was also usually the most snow (Appendix 6). An exception occurred in spring 1999. The total snow pack depth and water equivalency for the three fields during winter 1998/99 was similar to that in 1997/98, but the 1999 spring runoff volumes were only between 2% – 59% of those in spring 1998. This was due to the extended period of runoff in 1999. Snow pack/water equivalency amounts during the initial runoff period in March 1999 were considerably lower than during March 1998 and this caused lower spring runoff volumes. It was a late snowfall in April 1999 that increased the total snow pack amounts to equal those of 1998 (Appendix 6). However, by this time the ground thaw was much more advanced and would have allowed more infiltration of the snowmelt into the ground instead of running off in surface overland flow.

For all years the snow pack depth near the onset of spring runoff was greater from the ZT field than the CT field (Appendix 6). This was considered due to more crop residue and plant matter left on the surface of the ZT field than the CT field. This material would help trap and hold more snow. Also, the ZT field was on the eastern side of the CT field. Prevailing westerly winds would help blow snow from more westerly locations (including the CT field) onto the ZT field. Elliot *et al.* (2001) generally found that snow accumulation was not so much affected by tillage or cropping system than the snow distribution was affected by surface cover. In the three years of their study (1995 – 1997) in a Saskatchewan watershed they observed more snowmelt runoff per unit area of two ZT basins than a CT basin.

4.2.2 Post-Spring Runoff

There were no measurable post-spring runoff events from the MW field between 1998 - 2000. As well, there were no runoff events recorded from the Twin Watershed CT or ZT fields during 1998. A few runoff events from the CT and ZT fields occurred during 1999 and 2000 (Appendices 5c and 5e). Similar to spring observations, total runoff (m^3) and unit area runoff (m^3 ha^{-1}) values from the ZT field were usually higher than from the CT field (Table 2).

Reasons why flows and runoff volumes were usually greater from the ZT field than the CT field are not fully known and probably occur due to a number of factors. Both fields had the same crop type planted each year since 1991 so the different land management practices (*i.e.*, conventional-till vs. zero-till) could have been a primary determining factor. Soil moisture replenishment and retention in the ZT field may be higher resulting in the need for less moisture penetration during precipitation events. The ZT field could be getting greater moisture replenishment in spring through long established worm hole and other forms of macropore development that would not be disturbed as much as on the CT field. More plant residue on the ZT field soil surface could also act similar to a mulch covering and cause less soil surface exposure to the elements in spring and early summer. Vegetation residue can reduce evaporation loss and help retain moisture in the soil for longer periods. Alternatively, a denser vegetation cover on the soil surface under an established crop canopy may also be shedding more moisture than on a more barren CT field soil surface.

4.3 Water Quality

4.3.1 General

Calculated mean values for water quality data of runoff collected from the MW weir and Twin Watershed CT and ZT weirs as well as background data of field runoff from the NWA and FF are provided in Appendices 7 – 10[10]. The following discussion focused on these five sites since they were the key areas of interest. As previously mentioned in Section 3.3, water samples from the MW, CT, ZT and NWA sites were analyzed at the Environment Canada laboratory in Saskatoon, Saskatchewan, and these results were used in the following discussion to keep consistent between years. Data used that was analyzed at Enviro-test Laboratory in Winnipeg included fecal coliform data for all sites and chemistry data from the FF. Some replicate water samples from the MW, CT, ZT and NWA sites were sent to Enviro-Test laboratories for chemical analyses to compare with the Saskatoon laboratory so the compatibility of water quality results from the FF to the other sites could be assessed.

The NWA was considered to be in a relatively natural state with little influences except from wildlife. The FF was also considered to have minimal influences other than from wildlife activity and had not received any fertilizer since about 1994.

Water quality data collected from sampling locations on watercourses receiving runoff from the field sites are also provided in Appendices 7 - 10. However, discussion has been limited on these ancillary sites because they were not the focus of the study and the data was often too limited to conduct adequate interpretation. For example, how the small dam reservoir (received MW drainage) affected runoff from the MW field before it was discharged to the downstream drainage site (#5, Figure 3) was beyond the design of this study.

4.3.2 Spring Runoff

4.3.2.1 Fecal Coliform Bacteria

Fecal coliform bacteria (FC) are present in the intestinal tracts of all warm-blooded animals. They provide a surrogate measurement indicating the possible contamination of water by sewage from septic or municipal systems, runoff from livestock facilities or direct livestock access to water, or by wildlife activity in an area. Higher FC counts generally indicate a greater possibility that other more harmful pathogens could occur and vice versa. However, other more harmful pathogens could still be present in the absence of FC.

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[10] Inquiries about availability of raw chemical data analyzed at the Environment Canada laboratory should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Mean FC counts in runoff from the MW and Twin Watershed CT and ZT fields were relatively low with values < 20 organisms 100 mL^{-1} (Figure 10). Fecal coliform bacteria values from the NWA were also low and usually less than the laboratory detection limit (< 10 organisms 100 mL^{-1}). Mean FC counts from the FF were usually higher than observed from the other field sites (Figure 10). During 1998, the mean FC count from the FF was less than the laboratory detection limit. In subsequent years, however, the mean values were greater than 100 organisms 100 mL^{-1} (Figure 10). The highest mean value was 440 organisms 100 mL^{-1} and occurred during 2000. This value maybe somewhat inflated because only one water sample was collected from the FF in 2000. This happened to be the second highest daily value observed between 1998 - 2001. The highest FC count from the FF occurred in 1999 and was 610 organisms 100 mL^{-1} (Appendix 8b). However, FC samples from several other days during 1999 were lower and reduced the overall seasonal mean to < 150 organisms 100 mL^{-1}. It is presumed a similar condition would have occurred from the FF in 2000 if more samples were collected.

It is not known what caused higher FC values in the FF compared to the other field sites, but it is suspected that it came from wildlife in the area. Several successive days of FC values above laboratory detection limits in some years such as 1999 indicated a relatively constant source was available. Since this was a forage field covered with abundant vegetation and adjacent to a relatively large bush land area, the population of rodents and other small animals (*e.g.*, mice, rabbits, etc.) as well as larger game was probably fairly high and contributing to FC counts.

These data indicated that spreading hog manure and incorporation in the fall was not causing any greater contributions of FC than from other areas. The low values observed in the MW field runoff suggested bacteria in hog manure applied in the fall had died off and were not being transported with runoff flows. Fecal coliform densities in animal manure are usually very high with values in the range of millions of organisms 100 mL^{-1} (Chandler *et al.* 1981, Brockamp 1993) so elevated values on manure spread fields could be expected. Higher FC counts occasionally occurred at sites upstream of the MW field (#8 and #6, Figure 3) and the non-manured Twin Watershed sites (# 1- #4, Figure 4; Appendices 7 - 10). This provided further indication there was not any more concern with FC counts from the MW field than other sites without manure applications. The low FC values in runoff from the MW were not totally unexpected because the manure was spread in the fall and incorporated into the soil within 48 - 72 hours after application. The duration of the winter period would provide time for die-off of FC. Green (1996) also found relatively low FC densities in runoff water from fields that had hog manure applied in late fall on frozen ground and early to mid winter over snow. Fecal coliform bacteria were observed to decline to non-detectable values within 60 d after application with the most rapid mortality occurring after fall application in Kentucky (Stoddard *et al.* 1998). Fecal coliform content in soil declined to pre-application values within 2 – 3 months dependent upon exposure and soil temperature (Elliot and Ellis 1977), and excepting winter applications, rate nor timing of manure treatments significantly affected FC content in surface or sub-surface drainage (Culley and Phillips 1982). However, spreading of manure too late in winter or early spring just

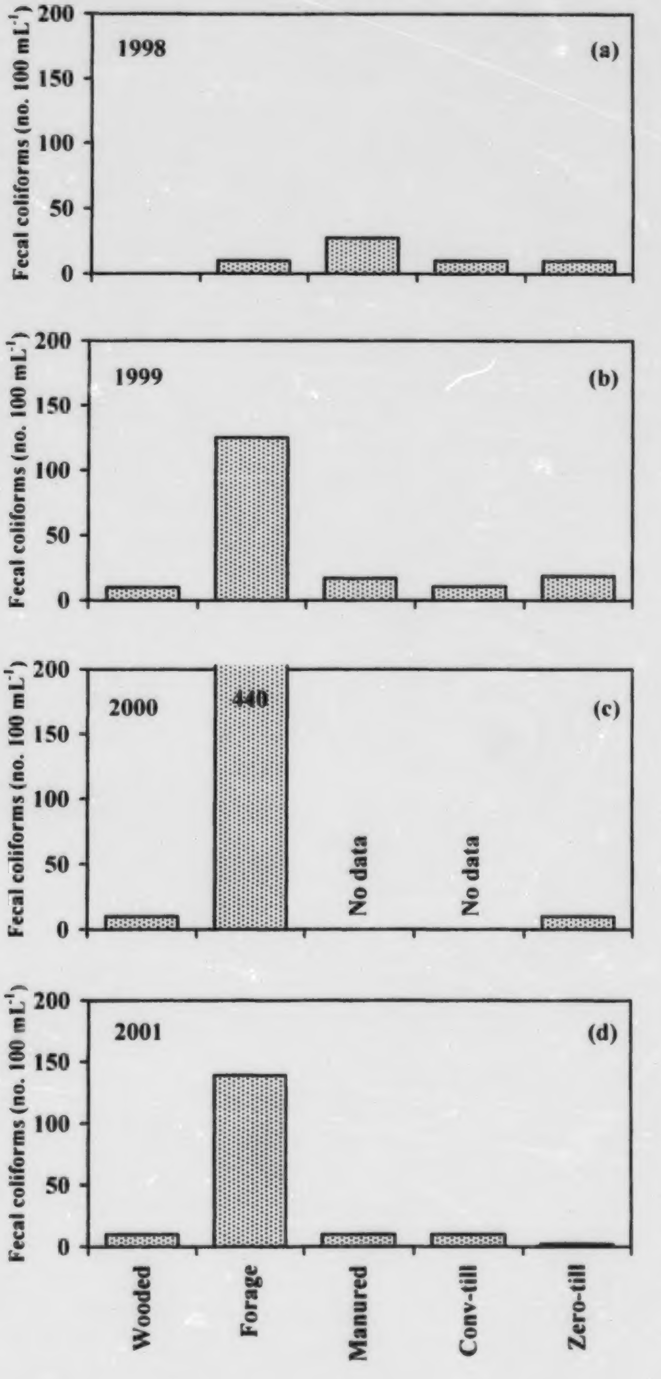

Figure 10. Mean fecal coliform densities (no. 100 mL^{-1}) from the Natural Wooded Area, Forage Field, Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

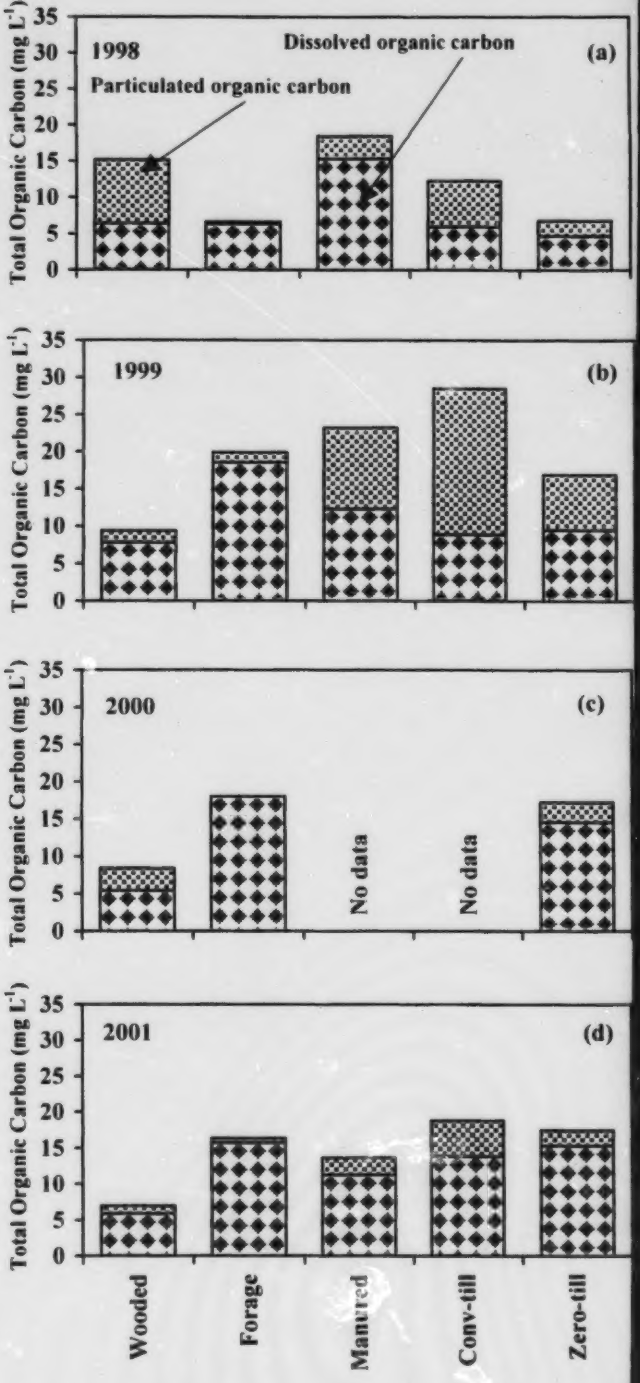

Figure 11. Mean organic carbon concentratons (mg L from the Natural Wooded Area, Forage Fie Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 2001.

prior to runoff may not allow a similar reduction under Manitoba conditions. For example, high FC counts (hundreds of thousands of organisms 100 mL^{-1}) were observed in runoff water from a field in Manitoba that was spread only a few weeks prior to spring thaw (Keryluk 1995).

Low FC values from the Twin Watershed CT and ZT fields were generally expected because manure was not spread on these areas. Some incidents of higher FC values were not totally unexpected either because small rodents and other wildlife could provide fecal matter to these field areas if habitat conditions were favourable. The ZT field conditions were more conducive to small mammal habitat than the CT field. There was more crop residue or other vegetation cover on the ZT field compared to the CT field. Less tillage on the ZT field would also reduce the destruction of borrows created by small mammals. Fecal coliform counts from both fields were generally less than laboratory detection limits except in 1999 (Appendices 7 – 10). During 1999, FC counts in the ZT field were slightly higher than the CT field (Figure 10).

Some daily FC coliform counts in the receiving stream of the non-manured Twin Watershed location were considerably higher than what occurred from the MW field. Daily fecal counts from the sampling sites on this creek (sites #1 and #2, Figure 4) were usually at laboratory detection limits, except during 1999 and 2000. Some of the highest FC values from these two locations were between 1000 - 5000 organisms 100 mL^{-1} (Appendices 8c and 9b). It is not known where these contributions originated, but the most plausible explanation is from wildlife activity near this location. No manure applications or pastureland occurred in the immediate vicinity of this site and values from the Twin Watershed fields were considerably lower. Riparian vegetation and bush land along this creek was fairly extensive and would have provided suitable habitat and shelter for wildlife. However, the daily value of 5100 organisms 100 mL^{-1} during February 22, 2000 (Appendix 9b) was considered high to what has generally been observed from natural sources in Manitoba. Fecal coliform values in the range of hundreds to a thousand organisms 100 mL^{-1} can occur, especially in areas where there may be considerable waterfowl or beaver activity (Manitoba Conservation unpublished data).

4.3.2.2 Carbon

Carbon is one of the most common elements and a fundamental element of living organisms. Carbon can be in an inorganic form (compounds in water such as calcium carbonate and carbonic acid that influence pH, alkalinity, and water hardness) or in an organic form (carbon associated with organic matter such as plant and animal tissues). Organic carbon was measured from the study sites since sources such as animal manure and vegetation decay provide contributions to carbon loading.

Mean total organic carbon (TOC) concentrations from the study sites ranged between approximately 5.0 – 29.0 mg L^{-1} (Figure 11). During 1998, the greatest mean TOC concentration (18.4 mg L^{-1}) occurred from the MW field. This was also the year with the greatest spring runoff flows from all fields. Organic carbon in hog manure can be fairly high. Since there were relatively good runoff flows from the MW field during 1998, higher mean TOC concentrations from this field were not unexpected. However, it was not anticipated that the largest mean concentration of TOC (~ 28.4 mg L^{-1}) observed during this study would occur from the CT field in 1999 (Figure 11). The highest mean

TOC concentration (~ 18.8 mg L^{-1}) during 2001 also was from this field. The low volume of runoff from the MW field during 1999 - 2001 greatly reduced the opportunity for carbon loss and it was not known if concentrations would have been as high as from the CT field. ANOVA pairwise comparisons between sites were generally not significant ($p \leq 0.05$) except between the NWA and the other sites (Appendix 11). The lowest concentrations of total organic carbon usually occurred at the NWA (Figure 11).

Dissolved organic carbon (DOC) usually comprised the major portion (> 60 % and often between 75 % - 95 %) of organic carbon in spring runoff flows (Appendices 7 – 10). Except for 1998, DOC concentrations from the FF were higher than from any other site. The low DOC value for the FF in 1998 compared to other years was probably due to a poor representation of samples for that year. Only one sample was collected from the FF during 1998 and this sample came near the end of the runoff period when concentrations of substances in runoff water were frequently lower. Mean DOC concentrations from the FF were always slightly higher than from the ZT field, presumably because a denser vegetation cover provided the opportunity for greater contributions from organic decay. Likewise, DOC concentrations were usually slightly higher from the ZT than the CT field. None of the differences between these fields were significant ($p \leq 0.05$) except between the FF and ZT field during 1999 (Appendix 11). Although ground cover was not measured on the FF field, the percent ground cover laying flat on the ZT field (54 % – 62 %) was always higher than from the CT field (7 % – 23 %) between 1998 – 2001 (Deerwood Soil & Water Management Association data not presented in this report). Higher concentrations of DOC were also observed in tributaries from a Maine River basin that were dominated by forest and wetland cover compared to those with extensive agriculture (Cronan *et al.* 1999).

Although greater amounts of groundcover on the FF or ZT fields than the CT field may explain why these fields had higher DOC concentrations than the CT field, it did not fully explain why the CT field had the highest mean TOC concentration during 1999 and 2001 (Figure 11). Concentrations from both these years were significantly greater ($p \leq 0.05$) than the lowest mean concentration in 1998 (Appendix 12). These higher TOC concentrations from the CT field in 1999 and 2001 occurred because of greater concentrations of particulate organic carbon (POC) compared to other fields (Figure 11). Higher TOC values from the CT field than from the MW field or the ZT field was somewhat unexpected because there was less organic matter visible on the soil surface. However, changes in TOC concentrations and differences observed between fields were probably due to numerous factors that are part of complex interrelated systems and are not easily explained. As environmental, soil moisture and other conditions change there is not necessarily a consistent cause and effect relationship. Green and Turner (2000) proposed higher concentrations of POC during 1999 than in 1998 might have been due to the reduced dilution effects by the much lower runoff in 1999. Total suspended sediment from watersheds on the Atlantic Coastal Plain had a higher nutrient and organic carbon content at base (lower) flows with the percentage of organic carbon content declining as flow rates increased (Correll *et al.* 1999). However, they also found that most organic carbon was in the dissolved phase at base flows and in a suspended solid phase when flows were higher, although most watersheds in their study were 3 – 50 times larger than the fields in this study. Green and Turner (1999) also noted a higher TOC concentration from the CT field than the ZT field in 1998 probably occurred due to a freer flow of runoff water able to carry particulate matter. The ZT field, and to some extent the MW field, had more crop residue and vegetation matter left on the field surface. Although this dead vegetation is a source for organic carbon, it would also help trap debris and filter out some particulate matter from diffuse overland flow.

4.3.2.3 Nitrogen

Nitrogen comprises approximately 80 % of the earth's atmosphere and is an important element for plant and animal growth. Atmospheric N is unavailable to most plants and animals until microorganisms convert it from gaseous N to useful inorganic compounds.

Total nitrogen (TN) in water can be comprised of particulate nitrogen (PN - usually associated with organic matter such as plant materials) and dissolved nitrogen (DN - readily available for plant uptake) forms. Particulate nitrogen is unavailable to aquatic plants and organisms because it is bound with organic matter and must be converted to an inorganic form to become available. Inorganic N readily utilized by plants occurs as ammonia-N and nitrate-nitrite-N. Dissolved nitrogen in aquatic systems is generally comprised of these forms of nitrogen.

The highest mean value of TN occurred at the MW weir during 1998 and was approximately 18.3 mg L^{-1} (Figure 12a). Mean TN concentrations from this field in subsequent years were less than a quarter of the 1998 concentration (significantly less at $p \leq 0.05$, Appendix 12). The second highest mean TN concentration (~ 16.4 mg L^{-1}) observed between 1998 – 2001 came from the CT field during spring 1999 and this mean value was significantly greater ($p \leq 0.05$) than values from other sites in that year. It was not much lower than what occurred from the MW field in 1998. This TN value was more than double any mean concentration from the other sites during 1999 (Figure 12).

The higher mean TN concentration from the CT field in 1999 was initially unexpected. Soil test results from the fall of 1998 indicated that the residual nitrate-N value in the CT field was < 1 kg ha^{-1} (<1 lb $acre^{-1}$) in the upper 15 cm soil profile and a total of approximately 4 kg ha^{-1} (3 lb $acre^{-1}$) down to 60 cm (Appendix 4). However, verification of land use records and affirmation with the landowner revealed that approximately 67 kg ha^{-1} (~ 60 lb $acre^{-1}$) of anhydrous ammonia was applied to the CT field in the fall of 1998. This rate of application of anhydrous ammonia still provided a much lower N rate than what was estimated to have been available from the upper 15 cm soil horizon of the MW field. The nitrate-N in the MW field upper 15 cm soil profile after manure had been applied in the fall of 1998 was about 161 kg ha^{-1} (~ 144 lb $acre^{-1}$)(Appendix 4). The very low runoff volumes from the MW field were considered to have reduced the opportunity for movement of nutrients off the field. Spring runoff volumes went from 428 m^3 in 1998 to approximately 8 m^3 and 26 m^3 during 1999 and 2001, respectively. Runoff flows were not measurable from the MW and CT fields in 2000 (Table 2) and the absence of runoff from the CT field also probably prevented a loss in 2000 similar to 1999. Approximately 67 kg ha^{-1} (~ 60 lb $acre^{-1}$) of anhydrous ammonia was also applied to the CT field in the fall of 1999. However, because there was no measurable runoff from the CT field in spring 2000, a loss of N similar to that observed in spring 1999 never occurred. Tokarz *et al.* (1979) also observed lower nutrient values from experimental plots at the University of Manitoba Glenlea Research Station occurred

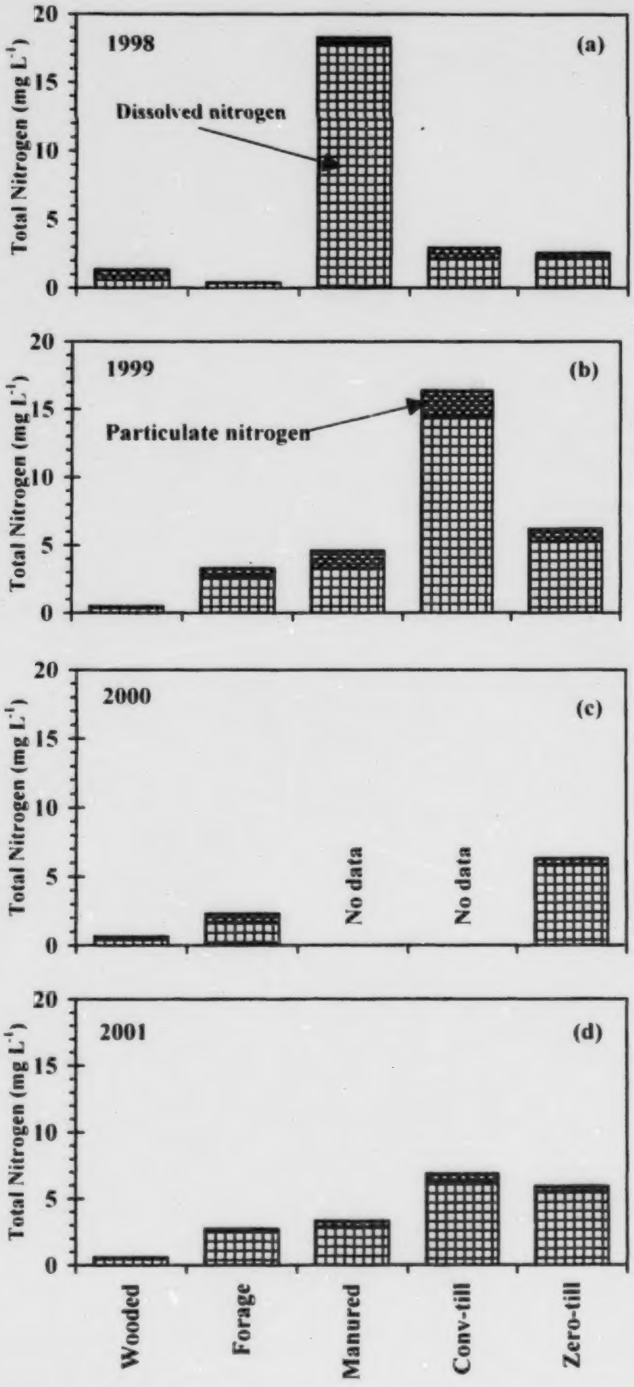

Figure 12. Mean total, dissolved, and particlulate nitrogen concentrations (mg L^{-1}) from the Natural Wooded Area, Forage Field, Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

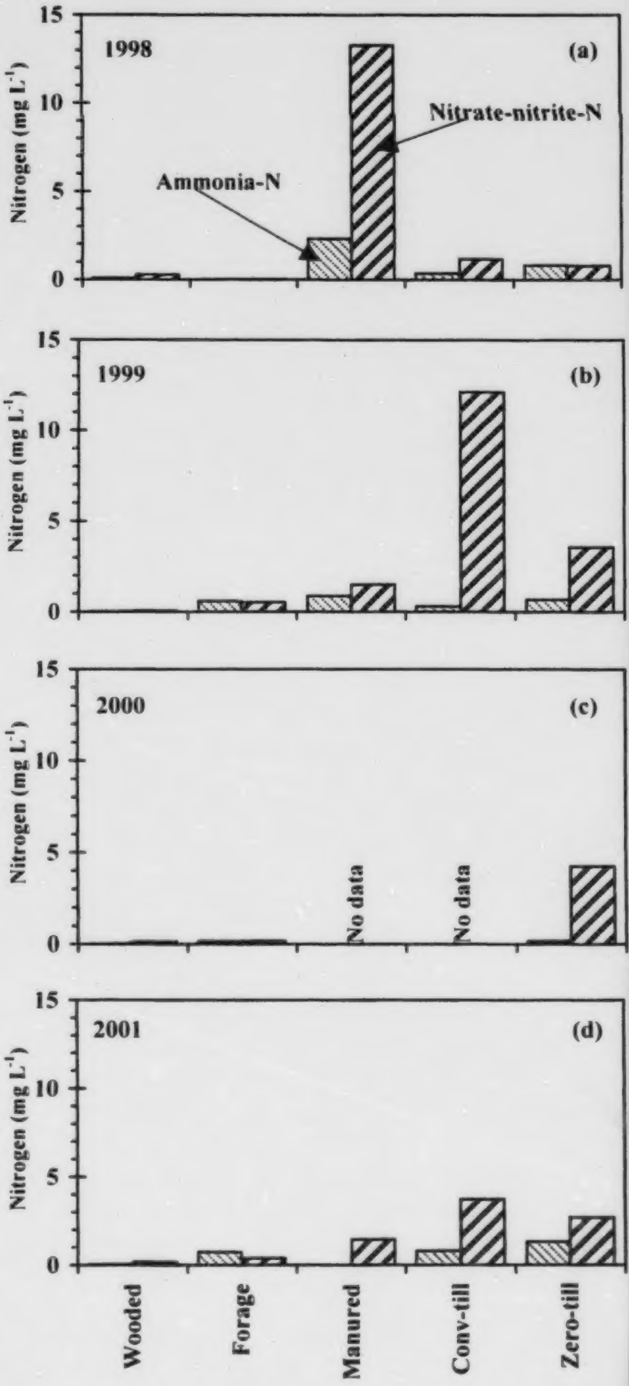

Figure 13. Mean ammonia-N and nitrate-nitrite-N concentrations (mg L^{-1}) from the Natural Wooded Area, Forage Field, Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

during a year when snowmelt runoff was much lower than compared to the other two years of the study.

Very low spring runoff flows from the MW field between 1999 – 2001 appeared to have mitigated transport of high N concentrations off field, at least in concentrated discharges over short-term measurable runoff events. This study was not capable of measuring trickle or seepage flow so it is not known what nutrients could have been transported during these types of events. Less diffuse flow over this field between 1999 - 2001 than what occurred in 1998 would reduce the exposure area for contributing to the N load. Even though the lower volume of runoff could increase the concentration due to less dilution, the volume of runoff was so low that it probably helped keep the nitrogen concentration low as well. Under conditions with higher runoff flows, water from the far reaches of the field would be picking up nutrients and increasing concentrations as it travelled towards the weir. During 1999 and 2001, field observations indicated that runoff only came from the area near the weir and had less opportunity for nutrient accumulation. Concentrations of TN in runoff from land under tillage and pasture in the Roseisle Creek Watershed (in the vicinity of South Tobacco Creek) decreased to less than half from 1998 to 1999 in conjunction with a substantially reduced spring runoff event during 1999 (Manitoba Conservation unpublished data).

The mean TN concentrations from the NWA and FF were relatively low and generally significantly ($p \leq 0.05$) less than compared to the other sites (Figure 12, Appendix 11). The mean TN concentration from the NWA was very low and tended to be < 1.0 mg L^{-1} while mean values from the FF were usually between 2.0 – 3.0 mg L^{-1} (Figure 12). Total nitrogen concentrations between years for the FF and NWA were usually not significant while greater variability caused more significant between year relationships for the other sites (Appendix 12).

Dissolved inorganic-N is important to plants because it is usually in a readily available form for uptake. The greatest portion of N in spring runoff from all five sampling sites was the dissolved form. Nitrate-nitrite-N was the dominant form of dissolved inorganic-N from most sites (Figure 13). Nitrate-nitrite-N from the NWA was significantly ($p \leq 0.05$) lower than all sites except the FF site during 1998 (Appendix 11). Cronan *et al.* (1999) also noted that nitrate-N was generally lower in streams dominated by forest cover and elevated in streams dominated by agriculture. Higher values of nitrate-nitrite-N compared to ammonia-N from the MW field and CT field was somewhat unexpected given that anhydrous ammonia was used on the CT field during fall 1998 and 1999 and nitrogen in hog manure (Table 1) was mainly ammonia-N. This was somewhat different from observations by Tokarz *et al.* (1979) on manured research plots at the Glenlea Research Station between 1976 - 1978. Their data usually indicated that ammonia-N concentrations were usually predominant over nitrate-N concentrations in snowmelt runoff, although nitrate-N concentrations were higher than ammonia-N concentrations during 1977 when runoff volumes were low. The predominance of nitrate-nitrite-N in spring runoff in this study indicated that conversion from ammonia-N to nitrate-N was occurring relatively quickly after application in fall. Pierson *et al.* (2001) noted ammonium nitrogen concentrations in single runoff events increased soon after broiler litter application. They also observed the concentrations decreased fairly rapidly after applications and considered this to be due to volatilization, oxidation to nitrite-N and nitrate-N in soil and utilization by microorgansims. The relatively high concentration of N from the CT field during spring 1999 indicated that the loss of nutrients to surface water from fields applied with commercial fertilizers could also occur when conditions are suitable.

The N loss from the MW and Twin Watershed weir locations was not evident in the receiving channels. Mean concentrations of TN at the downstream sampling site in the receiving channels (Site #5 – MW and site #1 – Twin Watershed; Figures 3 and 4, respectively) were lower than at the upstream sampling locations (Appendices 7 - 10). For example, mean TN concentrations at the upstream (site #2) and downstream (site #1) sites on the receiving stream of the Twin Watershed during 1999 were approximately 10.2 mg L^{-1} and 7.1 mg L^{-1}, respectively (Appendix 8c). Although the mean TN concentration from the CT field was approximately 16.4 mg L^{-1} (Appendix 8a), the diluting effect of the larger volume of water in the receiving stream appeared to be diluting and masking the higher concentration from this field in 1999. The larger volume of runoff from the ZT field (~ 2600 m^3) compared to the CT field (~ 750 m^3) would also have reduced the effect of the higher concentration from the CT field. The mean TN concentration from the ZT field (~ 6.2 mg L^{-1}) was lower than concentrations from the CT field or at the downstream site (#1) on the receiving stream (Appendices 8a and 8c).

4.3.2.4 Phosphorus

Phosphorus is an essential nutrient for all living organisms. Total phosphorus (TP) includes particulate phosphorus (PP - associated with silt or organic matter such as algae, leaves, and other plant matter) and dissolved phosphorus (DP - portion readily available to aquatic plants such as algae).

Mean TP concentrations showed similar trends to those for N during 1998, but not in other years. The mean TP concentration from the MW field was significantly ($p \leq 0.05$) higher than other fields when there had been reasonably substantive spring runoff flow during 1998 (Figure 14a, Appendix 11). The mean TP concentration from the MW field in 1998 was approximately 2.3 mg L^{-1} compared to between < 0.1 – 0.5 mg L^{-1} from the other locations (Figure 14a). The highest mean TP concentrations during 1999 came from the FF and MW fields where values were very similar (~ 1.3 mg L^{-1}, Figure 14b). During 1999, mean TP from the FF, MW, CT and ZT fields were not significantly different from one another, but all were significantly greater ($p \leq 0.05$) than TP from the NWA (Appendix 11). Total phosphorus from most sites was usually significantly higher than concentrations from the NWA between 1998 – 2001.

No data were obtained from the MW field during 2000 because there was no measurable runoff. Except for the NWA, which had a very low mean TP concentration (~ 0.1 mg L^{-1}) in 2001, the mean TP concentration from MW field during 2001 was lower than other locations (Figure 14), but was not significantly different ($p \leq 0.05$) from the FF, CT or ZT fields (Appendix 11). The mean TP value from the MW field during 2001 was only about 0.8 mg L^{-1}. In comparison, mean values for the CT and ZT fields during 2001 were approximately 1.4 mg L^{-1} and 2.7 mg L^{-1}, respectively (Figure 14d). In fact, the mean TP value for the ZT field in 2001 was the highest value observed from the field sites between 1998 – 2001 (Figure 14).

Higher P values from the MW field than the CT or ZT fields during spring 1998 could be explained by the much higher values in the soil from the MW field during the

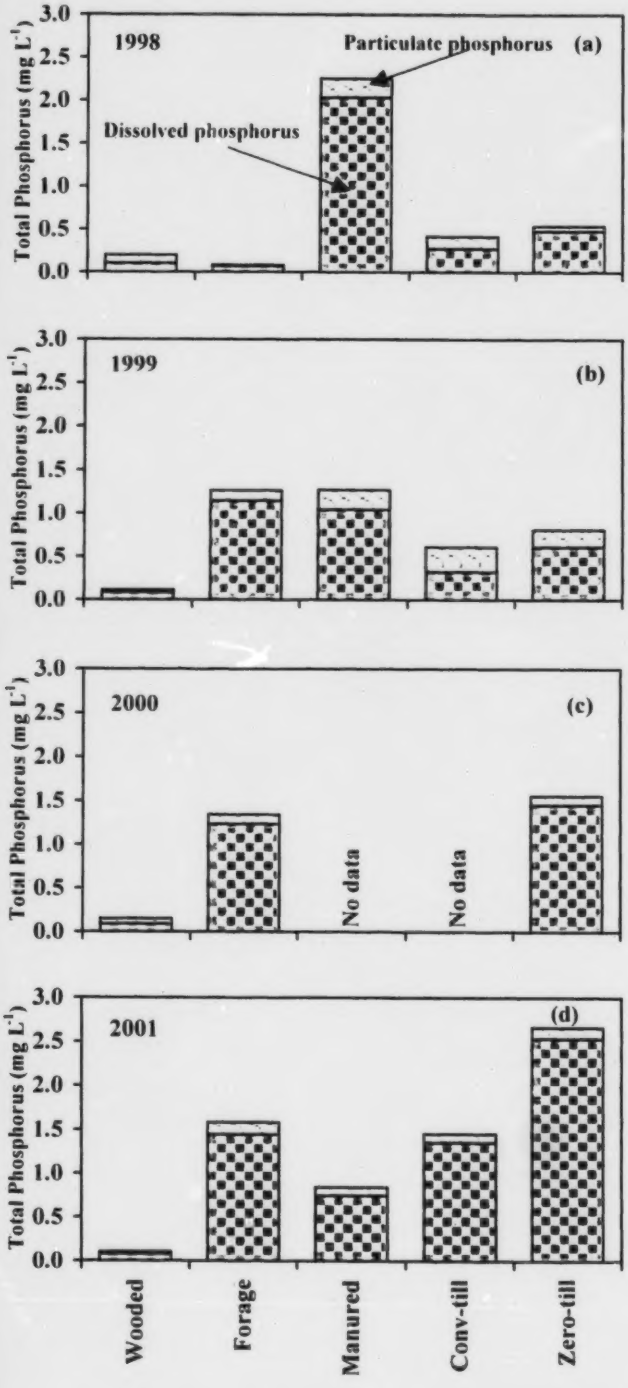

Figure 14. Mean total, dissolved, and particlulate phosphorus concentrations (mg L^{-1}) from the Natural Wooded Area, Forage Field, Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

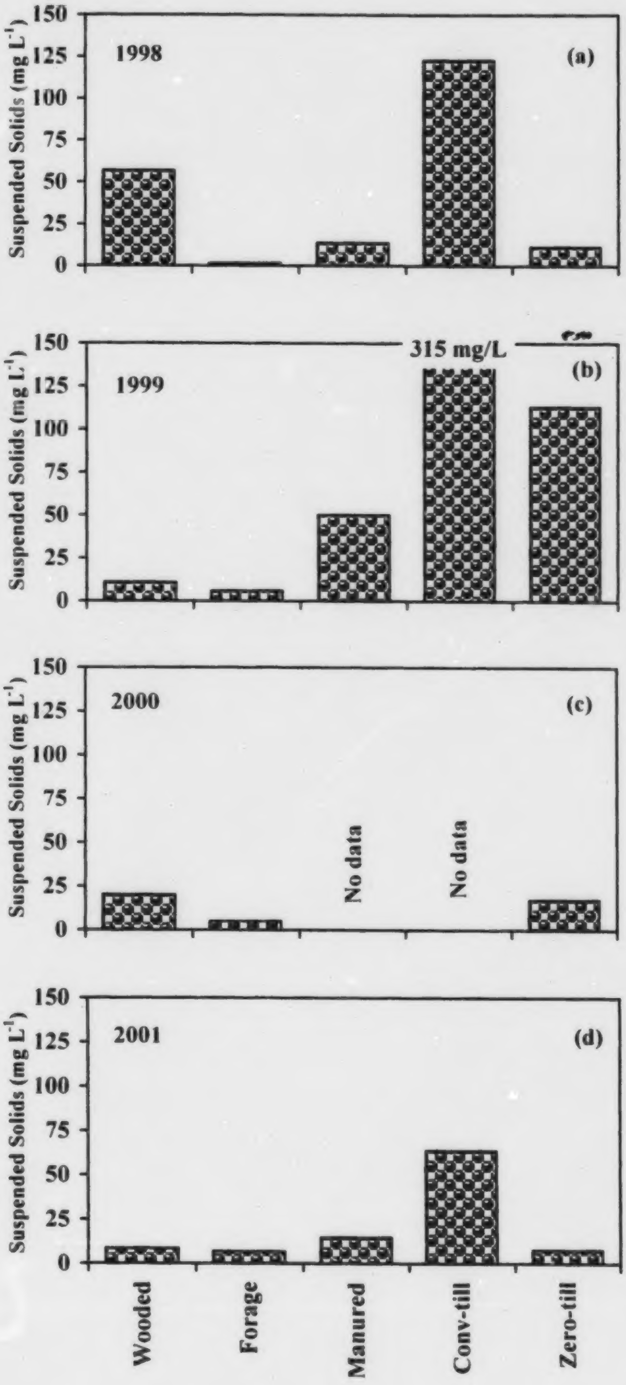

Figure 15. Mean suspended solid concentrations (mg L^{-1}) from the Natural Wooded Area, Forage Field, Manured Watershed , Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

fall of 1997. The soil residual P value in the MW field upper 15 cm during fall 1997 was 73 kg ha^{-1} while values for the CT and ZT field were only between 29 – 47 kg ha^{-1} (Appendix 4). An additional estimated 21 kg ha^{-1} of P was also added with the manure application[11] to increase the TP to approximately 84 kg ha^{-1}. It was, however, not fully known from the data why runoff TP concentrations from the other sites were generally similar to or higher than those concentrations from the MW field between 1999 – 2001. Phosphorus values in the soil profile from the MW field were always relatively high compared to those for the CT or ZT fields (Appendix 4).

As discussed in previous sections, it was speculated that the substantial reduction in runoff volumes of the MW field from a high of 428 m^3 (1998) to < 30 m^3 in other years caused the reduced concentrations between 1999 – 2001. Comparison of soil test results between the fall of 1997 and 1998 indicated that P values were higher in both the upper 15 cm and the 15 - 60 cm profile during the fall of 1998. Consequently, it would be expected that P concentrations in runoff during the spring of 1999 should have been higher instead of lower than in the spring of 1998. Although a reduction in runoff volume can increase concentrations because of a lower dilution factor, observed conditions at the MW weir indicated the opposite effect probably occurred. During spring runoff 1999, the only flow appeared to come from the immediate vicinity of the weir. Less diffuse flow from all reaches of the field would reduce the exposure area for contributing to the P load. During the spring of 1998, there were six days that flows attained 1 L s^{-1} with a maximum flow almost reaching 6 L s^{-1} on March 27 (Yarotski and Miller 1999). Runoff water from most of the field area appeared to contribute to flows. Meanwhile, flows during 1999 only lasted two days with a maximum flow of < 0.30 L s^{-1} on March 15 (Yarotski and Miller 2000). The area in front of the weir was mainly groomed (short cut) grass that had been established for controlling sediment disturbance and pickup due to influences on flows interrupted at the weir. This grass strip was managed the same as the grass strips behind the CT and ZT fields. Manure application was not targeted on this area and the nutrient availability would be relatively small given the maintenance of the grass.

An interesting observation from the data was the increasing value of TP concentrations from the FF and ZT field between 1998 – 2001. Increases in annual P concentrations for the FF were not as significant as for the ZT field and generally were within 6 % – 30 % between 1999 to 2001 (Figure 14). However, annual P concentration increases for the ZT field went from 50 %, 90 %, and 72 % between 1998 to 1999, 1999 to 2000, and 2000 to 2001, respectively. Between year differences in mean TP concentrations were usually not significant for the FF and significant ($p \leq 0.05$) for the ZT field (Appendix 12). A similar pattern may have been occurring for the CT field as well, but the absence of data in 2000 precluded confirmation. Causes for these increased concentrations in the ZT field and variability between years for the other fields are not fully known. Studies elsewhere have found concentrations of DP, bioavailable P and other chemicals often increase under no till conditions (Eghball and Gilley 1999, Scheiber and Cullum 1998, Sharpley *et al.* 1994, McIssac *et al.* 1993, Laflen and Tabatabai 1984, Baker and Laflen 1983). Sharpley *et al.* (1981) found P leaching from vegetation cover contributed significant amounts of soluble P in unfertilized watersheds.

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[11] This equated to an additional available amount of approximately 10.5 kg ha^{-1} TP or 24 kg ha^{-1} P_2O_5 assuming 50 % availability for crops.

Phosphorus availability has been described to vary appreciably depending upon numerous factors such as agricultural practices and various dynamic physical and chemical processes controlling the forms of P (Sharpley *et al.* 1992). Hooda *et al.* (2000) noted soil P content or P sorption capacity showed a poor relationship with the amount of P potentially released to water; the most important property was the extent soils were saturated with P. There was much greater potential to have high dissolved molybdate reactive P and available algal P with manure applications in conjunction with ZT than other tillage practices (Mueller *et al.* 1984), while increased residue cover reduced sediment load and subsequent TP loss (Bundy *et al.* 2001, Mueller *et al.* 1984).

There was not a weir at the FF field to measure flows so the variability of flows was not known between 1999 to 2001, although it was expected that general annual patterns in runoff from other sites would also occur at the FF. Runoff volumes from the ZT field decreased from approximately 4400 m^3 to 2600 m^3 to 1900 m^3 between 1998 to 2000. These decreases may have caused some concentrating of P values, but this was not consistent with what occurred during 2001. The highest P concentration occurred in this year while the runoff volume (~ 3300 m^3) was only the second highest for the four years. Schreiber (1999) noted that crop residues left on the soil surface were effective in reducing erosion but there was also a significant source of soluble nutrients to runoff. It could have been that more organic matter was gradually accumulating on these two fields each successive year and the amount of P available for loss was increasing. Environmental conditions such as a delayed onset of freezing and milder winters may also provide for greater organic decay, release and availability of nutrients.

Similar to N and organic carbon, the dissolved form of P comprised the greatest proportion of TP at all sites. Dissolved phosphorus values usually comprised between 75 % – 90 % of the TP (Figure 14). High percentages of DP were also reported in runoff from pastureland in Australia (Nash *et al.* 2000, Tham 1983) and DP made up 91 % of bioavailable P in runoff from ZT fields applied with beef cattle manure (Egball and Gilley 1999). Tokaz *et al.* (1979) noted that P in snowmelt runoff from experimental plots at the Glenlea Research Station in Manitoba was mostly in the soluble form with ortho-phosphorus averaging about 85% of the total phosphorus. Dissolved phosphorus also usually comprised over 80 % of TP from land runoff in the Roseisle Creek Watershed in Manitoba during spring runoff 1998 and 1999 (Manitoba Conservation unpublished data).

Total phosphorus concentrations in receiving waterways showed similar trends previously described for N in Section 4.3.2.3. Mean concentrations of TP at the downstream sampling site in the receiving channels (Site #5 – MW and site #1 – Twin Watershed; Figures 3 and 4, respectively) were usually lower than at the upstream sampling locations (Appendices 7 - 12). For example, mean TP concentrations at the upstream (site #2) and downstream (site #1) sites on the receiving stream of the Twin Watershed during 1999 were approximately 0.9 mg L^{-1} and 0.7 mg L^{-1}, respectively (Appendix 8c). Similar conditions occurred in 1998 and for the MW as well. This indicated that the P loads from these fields were not causing significantly noticeable increases to stream concentrations.

4.3.2.5 Suspended Solids

Suspended solids (SS) are particles in the water column that can include clay, silt, and organic matter such as pieces of vegetation or even small aquatic organisms and plants. Suspended solids in high enough concentrations will impair light penetration through the water column. Fine soil particles often comprise the majority of SS in the water column in many prairie streams and rivers and this is what usually causes a murky appearance to water.

Suspended solid concentrations were consistently highest from the CT field and were usually significantly different compared to other sites (Appendix 11). Mean concentrations ranged between approximately 63 mg L^{-1} in 2001 to over 300 mg L^{-1} in 1999 (Figure 15). The lowest SS concentrations came from the FF. These values ranged between 1 – 7 mg L^{-1}. Mean concentrations from the NWA, MW field and ZT field were usually relatively low (ranging between 6 – 20 mg L^{-1}), except in 1999. During 1999, concentrations from the MW and ZT fields were approximately 50 and 113 mg L^{-1}, respectively. The mean concentration from the NWA in 1998 was also fairly high (~ 57 mg L^{-1}). As previously noted in Section 3.4, this value represented a mean of data from 1995 – 1997 (annual means ranging from 37 – 86 mg L^{-1}) since data was not collected from this site in 1998.

Higher SS concentrations could be expected from the CT field because it had less crop residue and other vegetation that would allow greater exposure and movement of soils by wind and water. Nutrients and sediment loss from turfgrass was very low compared to agronomic row crops (Gross *et al.* 1990) and increased residue on fields reduced erosion and sediment loads (Shreiber 1999, Mueller 1984). The ZT and MW fields received less tillage that allowed more plant residue on the surface. Similar to vegetation from the NWA or FF, this plant residue would help impede and trap soil particles being transported with runoff water. Decaying vegetation, however, also can contribute to suspended matter. If conditions are right, small enough particles from decaying plant matter can be transported with runoff. This was probably what occurred in some years when SS concentrations were relatively high from the NWA. Field observations during sample collections from the NWA between 1999 – 2001 indicated that suspended material appeared to be mainly vegetation material such as pieces of leaf litter and not soil particles.

The cause of higher SS concentrations from the MW and Twin Watershed CT and ZT fields in 1999 compared to other years is not known. Runoff volumes from all three sites were lower in 1999 than 1998 and this may have caused increased concentrations due to less dilution by runoff water. However, this cannot be the only explanation because data from other years did not always consistently follow this same pattern. For example, the runoff volume from the ZT field during 2000 was lowest of all years (Table 2), yet the SS concentration did not proportionally increase compared to what happened between 1998 and 1999. In fact, the mean SS value in 2000 was only about 15 % of what occurred in 1999 (Figure 15). On the other hand, the runoff volume from the ZT field during 2001 was the second highest for the four years of data. The mean SS concentration in 2001 was low (< 8 mg L^{-1}) and in a comparatively similar range to the concentration (~ 14 mg L^{-1}) for the highest runoff year in 1998. There did, however, appear to be a weak correlation between runoff volume and mean concentrations from the CT field. The maximum, median, and minimum runoff volumes (~ 3200 m^3, 2800 m^3, and 750 m^3, respectively) corresponded with the maximum, median, and minimum mean SS concentration from the CT field (Table 2, Figure 15).

Potentially greater turbulence from higher runoff flows impacting against the weir were not considered to have caused higher SS concentrations because of the groomed grassed area established behind each weir to compensate for the erosion effects of channelling runoff through the fixed weir. These grassed areas were regularly maintained to keep their conditions relatively consistent between sites.

4.3.2.6 Nutrient Loading

It is sometimes appropriate to make comparisons based upon nutrient loads because concentrations of nutrients and other substances can vary significantly with flow. One method to compensate for potential high variability of runoff conditions between sites and to provide a more balanced assessment of nutrient loss from the MW field and Twin Watershed fields was by standardizing to a unit area load, *i.e.*, areal loss in kg ha^{-1} (Table 3). Runoff volumes (m^3 day^{-1}), mean concentrations of nutrients (mg L^{-1}), estimated nutrient runoff load (kg day^{-1}), and total loading (kg runoff period^{-1}) from the MW field and the Twin Watershed CT and ZT fields used to calculate estimated losses are provided in Appendices 5a – 5f.

The greatest areal loss of N between 1998 – 2001 occurred from the MW field during 1998. Total nitrogen loss from the MW field in 1998 was approximately 8.63 kg ha^{-1} compared to losses of between 1.77 and 1.72 kg ha^{-1} from the CT and ZT fields, respectively. The range of losses from the Twin Watershed CT and ZT fields between 1998 – 2001 was approximately 0.81 – 3.67 kg ha^{-1} (Figure 16, Table 3). During the spring of 1998, total losses of nutrients from the MW field were higher than from the Twin Watershed sites despite the Manured Watershed only being about one-quarter the size of the other watersheds. However, compared to 1998, nutrient loss from the MW field between 1999 – 2001 was very small. As noted in previous sections, very low to negligible runoff from the MW field during these years was considered the main reason for such low off-field nutrient losses, especially for the spring runoff of 2000.

Although there would be some autocorrelation between the amount of runoff and total nutrient load transported off the field, numerous other factors also affect the variability of nutrient concentrations and ultimately the total load exported in runoff. How the total load coming off the field was affected by these factors was not clearly evident and further investigation of these factors was beyond the scope of this study. For example, runoff from the CT field was slightly lower in 2001 (~ 2800 m^3) compared to 1998 (~ 3200 m^3) yet the N loss in spring 1998 (~ 1.77 kg ha^{-1}) was only about half of what occurred in spring 2001 (~ 3.67 kg ha^{-1}, Figure 16). Runoff was very low in 1999 (~ 750 m^3) compared to 1998 and 2001, but the median N loss from the CT field (~ 2.13 kg ha^{-1}) occurred in this year. The main factor for a higher loss in 1999 than 1998 appeared to be the application of approximately 67 kg ha^{-1} of anhydrous ammonia-N the preceding fall. Soil test nitrate-N values in the upper 15 cm of soil during fall 1997 were considerably higher than in the fall of 1998 (~ 13 kg ha^{-1} and < 1 kg ha^{-1}, respectively; Appendix 4) so a higher loss would be expected in spring 1998 instead of spring 1999. However, the addition of anhydrous ammonia-N in the fall of 1998 increased the available N in spring 1999 to more than five times that for spring 1998. It is interesting

Table 3. Nutrient loss (kg ha^{-1}) from the Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

Year	Variable	Runoff Load											
		Manured Watershed				Twin Watershed							
		Manured Watershed field				Conventional-till Field (West Weir)				Zero-till Field (East Weir)			
		(0.89 ha)		(2.2 acres)		(4.24 ha)		(10.5 acres)		(5.64 ha)		(13.9 acres)	
		(Total kg)	(kg ha^{-1})	(Total lbs)	(lbs acre^{-1})	(Total kg)	(kg ha^{-1})	(Total lbs)	(lbs acre^{-1})	(Total kg)	(kg ha^{-1})	(Total lbs)	(lbs acre^{-1})
1998	Total Nitrogen	7.47	8.63	16.48	7.49	7.52	1.77	16.59	1.58	9.68	1.72	21.33	1.53
	Ammonia-N	1.10	1.26	2.43	1.10	1.23	0.29	2.72	0.26	3.38	0.60	7.46	0.54
	Nitrate-nitrite-N	5.39	6.20	11.88	5.40	2.93	0.69	6.45	0.61	2.72	0.48	6.00	0.43
	Total Phosphorus	1.12	1.25	2.46	1.12	0.96	0.23	2.12	0.20	2.03	0.36	4.47	0.32
	Dissolved Phosphorus	1.01	1.16	2.22	1.01	0.62	0.15	1.36	0.13	1.63	0.29	3.60	0.26
1999	Total Nitrogen	0.03	0.03	0.06	0.03	9.01	2.13	19.88	1.89	4.57	0.81	10.08	0.73
	Ammonia-N	0.01	0.01	0.02	0.01	0.20	0.05	0.43	0.04	0.54	0.10	1.20	0.09
	Nitrate-nitrite-N	0.01	0.01	0.02	0.01	7.06	1.67	15.57	1.48	2.28	0.40	5.03	0.36
	Total Phosphorus	0.01	< 0.01	0.01	0.01	0.32	0.08	0.70	0.07	0.85	0.15	1.86	0.13
	Dissolved	< 0.01	< 0.01	0.01	< 0.01	0.24	0.06	0.52	0.05	0.73	0.13	1.61	0.12
2000	Total Nitrogen	ND	ND	ND	ND	ND	ND	ND	ND	10.51	1.86	23.16	1.67
	Ammonia-N	ND	ND	ND	ND	ND	ND	ND	ND	0.23	0.04	0.50	0.04
	Nitrate-nitrite-N	ND	ND	ND	ND	ND	ND	ND	ND	7.51	1.33	16.56	1.19
	Total Phosphorus	ND	ND	ND	ND	ND	ND	ND	ND	2.47	0.44	5.44	0.39
	Dissolved Phosphorus	ND	ND	ND	ND	ND	ND	ND	ND	2.33	0.41	5.13	0.37
2001	Total Nitrogen	0.08	0.09	0.17	0.08	15.56	3.67	34.30	3.27	16.95	3.01	37.38	2.69
	Ammonia-N	0.01	0.01	0.02	0.01	2.28	0.54	5.02	0.48	4.50	0.80	9.92	0.71
	Nitrate-nitrite-N	0.03	0.03	0.07	0.03	7.91	1.87	17.45	1.66	7.19	1.27	15.85	1.14
	Total Phosphorus	0.02	0.03	0.05	0.02	3.48	0.82	7.66	0.73	7.50	1.33	16.53	1.19
	Dissolved Phosphorus	0.02	0.02	0.04	0.02	3.16	0.75	6.97	0.66	7.15	1.27	15.75	1.13

Note: Shading shows imperial measurements provided for convenience, but they may not coincide with precise conversions because of rounding.

ND = No data. Runoff from the Manured Watershed field and Conventional-till field negligible and too small to be measurable or to collect water samples.

Values from Appendix 5 rounded to nearest 0.1 kg and kg ha^{-1}.

Table 3. Nutrient loss (kg ha^{-1}) from the Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

Year	Variable	Runoff Load											
		Manured Watershed				Twin Watershed							
		Manured Watershed field				**Conventional-till Field (West Weir)**				Zero-till Field (East Weir)			
		(0.89 ha)		**(2.2 acres)**		(4.24 ha)		**(10.5 acres)**		(5.64 ha)		**(13.9 acres)**	
		(Total kg)	(kg ha^{-1})	**(Total lbs)**	**(lbs acre^{-1})**	(Total kg)	(kg ha^{-1})	**(Total lbs)**	**(lbs acre^{-1})**	(Total kg)	(kg ha^{-1})	**(Total lbs)**	**(lbs acre^{-1})**
1998	Total Nitrogen	7.47	8.63	**16.48**	**7.49**	7.52	1.77	**16.59**	**1.58**	9.68	1.72	**21.33**	**1.53**
	Ammonia-N	1.10	1.26	**2.43**	**1.10**	1.23	0.29	**2.72**	**0.26**	3.38	0.60	**7.46**	**0.54**
	Nitrate-nitrite-N	5.39	6.20	**11.88**	**5.40**	2.93	0.69	**6.45**	**0.61**	2.72	0.48	**6.00**	**0.43**
	Total Phosphorus	1.12	1.25	**2.46**	**1.12**	0.96	0.23	**2.12**	**0.20**	2.03	0.36	**4.47**	**0.32**
	Dissolved Phosphorus	1.01	1.16	**2.22**	**1.01**	0.62	0.15	**1.36**	**0.13**	1.63	0.29	**3.60**	**0.26**
1999	Total Nitrogen	0.03	0.03	**0.06**	**0.03**	9.01	2.13	**19.88**	**1.89**	4.57	0.81	**10.08**	**0.73**
	Ammonia-N	0.01	0.01	**0.02**	**0.01**	0.20	0.05	**0.43**	**0.04**	0.54	0.10	**1.20**	**0.09**
	Nitrate-nitrite-N	0.01	0.01	**0.02**	**0.01**	7.06	1.67	**15.57**	**1.48**	2.28	0.40	**5.03**	**0.36**
	Total Phosphorus	0.01	< 0.01	**0.01**	**0.01**	0.32	0.08	**0.70**	**0.07**	0.85	0.15	**1.86**	**0.13**
	Dissolved	< 0.01	< 0.01	**0.01**	**< 0.01**	0.24	0.06	**0.52**	**0.05**	0.73	0.13	**1.61**	**0.12**
2000	Total Nitrogen	ND	ND	**ND**	**ND**	ND	ND	**ND**	**ND**	10.51	1.86	**23.16**	**1.67**
	Ammonia-N	ND	ND	**ND**	**ND**	ND	ND	**ND**	**ND**	0.23	0.04	**0.50**	**0.04**
	Nitrate-nitrite-N	ND	ND	**ND**	**ND**	ND	ND	**ND**	**ND**	7.51	1.33	**16.56**	**1.19**
	Total Phosphorus	ND	ND	**ND**	**ND**	ND	ND	**ND**	**ND**	2.47	0.44	**5.44**	**0.39**
	Dissolved Phosphorus	ND	ND	**ND**	**ND**	ND	ND	**ND**	**ND**	2.33	0.41	**5.13**	**0.37**
2001	Total Nitrogen	0.08	0.09	0.17	0.08	15.56	3.67	**34.30**	**3.27**	16.95	3.01	**37.38**	**2.69**
	Ammonia-N	0.01	0.01	0.02	0.01	2.28	0.54	**5.02**	**0.48**	4.50	0.80	**9.92**	**0.71**
	Nitrate-nitrite-N	0.03	0.03	0.07	0.03	7.91	1.87	**17.45**	**1.66**	7.19	1.27	**15.85**	**1.14**
	Total Phosphorus	0.02	0.03	0.05	0.02	3.48	0.82	**7.66**	**0.73**	7.50	1.33	**16.53**	**1.19**
	Dissolved Phosphorus	0.02	0.02	0.04	0.02	3.16	0.75	**6.97**	**0.66**	7.15	1.27	**15.75**	**1.13**

Note: Shading shows imperial measurements provided for convenience, but they may not coincide with precise conversions because of rounding.

ND = No data. Runoff from the Manured Watershed field and Conventional-till field negligible and too small to be measurable or to collect water samples.

Values from Appendix 5 rounded to nearest 0.1 kg and kg ha^{-1}.

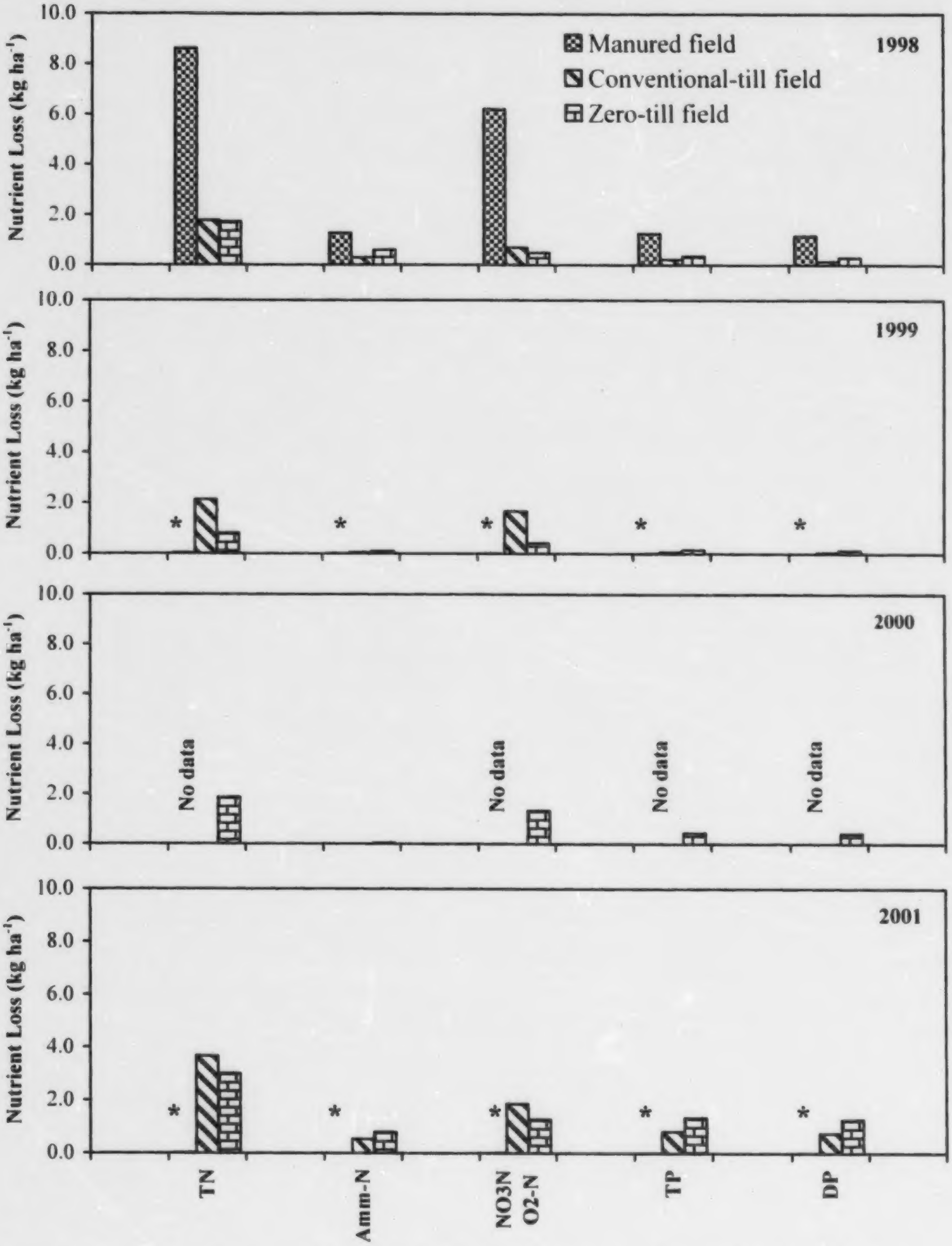

Figure 16. Nutrient loss (kg ha^{-1}) from the Manured Watershed field, and from the Twin Watershed Conventional-till and Zero-till fields during spring runoff, 1998 - 2001.

Note: No spring runoff data for Manured Watershed field or Conventional-till field in 2000.

*** = Total load from the Manured Watershed field was too small to be observable on this graph scale.**

TN = Total Nitrogen
Amm-N = Ammonia nitrogen
TP = Total Phosphorus
NO_3NO_2-N = Nitrate-nitrite nitrogen
DP = Dissolved Phosphorus

to note that an equivalent rate of application of anhydrous ammonia-N fertilizer during fall 1999 did not have the same consequence in the spring of 2000; a condition considered primarily due to no measurable runoff that year.

A similar pattern between runoff volumes and areal N losses occurred for the ZT field as well. The highest N loss from the ZT field (~ 3.01 kg ha^{-1}) also occurred during spring 2001 and this value was almost double the off-field load in spring 1998 (~ 1.72 kg ha^{-1}). This greater TN loss in 2001 was associated with a slightly lower spring runoff volume (~ 3300 m^3) and preceding fall soil nitrate-N value (~ 9 kg ha^{-1}) than for comparable conditions in 1998 (~ 4400 m^3 and 11 kg nitrate-N ha^{-1}) so some other factor/s apparently had more influence. Since patterns between the two fields were similar perhaps environmental conditions such as shorter milder winters play a major role. The TN runoff loss from the ZT field during 2000 (~ 1.86 kg ha^{-1}) was similar to that in 1998 (~ 1.72 kg ha^{-1}) even though the runoff volume in 2000 (~ 1900 m^3) was only about 42 % of that in 1998 (4400 m^3).

Each year, TN loss (kg ha^{-1}) was usually slightly higher from the CT field than the ZT field, while the opposite occurred for TP loss (Table 3). An exception occurred during spring 2000 because there was no measurable runoff from the CT field (Figure 16). Ammonia-N was higher in runoff from the ZT field than CT field, while nitrate-nitrite-N was higher in runoff from the CT field than the ZT field. This would appear logical since a greater amount of organic matter on the ZT field could initially provide more ammonia-N than what would be found on the ZT field. More nitrate-N could be expected from the CT field if nitrate based inorganic fertilizer was mainly used. During the fall of 1998 and 1999, however, the anhydrous ammonia application to the CT field (~ 67 kg ha^{-1}) was considerably greater than nitrate-N values in the upper 15 cm of soil (<1 – 9 kg ha^{-1}). As previously noted in Section 4.3.2.3, the higher concentrations and loading estimates of nitrate-nitrite-N than ammonia-N from this field in spring indicated that conversion of ammonia-N to nitrate-N was occurring between fall application and the spring runoff period.

Variations in soil N values between years may have been a key factor determining N loss, but the amount of influence was difficult to determine from this study. It was considered that during spring runoff (when deeper soils are still mainly frozen) most of nutrient loss would come from the upper 15 cm. If nutrients from near surface were the main source, higher N losses should have occurred from the MW field during spring runoff 1999 and 2001 instead of 1998 because there was more nitrogen in the top-soil (including added manure values) for each fall preceding those years (Figure 5a). Since this did not happen it further indicated that the very low runoff flows from the MW field between 1999 – 2001 were a greater influence at that time than soil nutrient values. It should be noted that soil N values between depths of 15 – 60 cm in the MW field were considerably higher in the fall of 1997 than any other fall and these values did coincide with the highest spring runoff losses from this field. Although considered unlikely, it was uncertain if nitrogen from deeper depths leached into surface runoff during spring thaw.

Observations for areal losses of P from the MW and Twin Watershed fields were similar to those for TN. The greatest TP loss from the MW field (~ 1.25 kg ha^{-1}) occurred during spring 1998, while it was during spring 2001 for both the CT (~ 0.82 kg ha^{-1}) and ZT (~ 1.33 kg ha^{-1}) fields (Table 3, Figure 16). These maximum losses from the CT and ZT fields in 2001occurred despite higher spring runoff volumes in 1998 (Table 2) and higher soil P values in the fall of 1997 (Appendix 4). Unlike for N, the highest areal P load between 1998 – 2001 did not come from the MW. The highest TP load was approximately 1.33 kg ha^{-1} from the ZT field and occurred during 2001 (Table 3, Figure 16).

Consistently higher P loads occurred from the ZT field than the CT field. This could also be expected because of the greater amounts of organic matter left on the field surface due to less tillage. Breakdown of this organic matter on the field surface of the ZT field would provide a greater opportunity for P pickup and transport in runoff than from the CT field. Very low to negligible runoff from the MW field between 1999 – 2001 prevented understanding how the much higher P values in soil on this field could contribute to off-field loading.

The apparent differences in runoff losses between years for the MW field and Twin Watershed CT and ZT fields were probably due to a number of factors and combinations of factors. It was clear a measurable loss did not occur when there was negligible runoff, but it was beyond the scope of this study and difficult to determine the degree and/or combination of factors that caused variations in nutrient losses between fields and between years for each field. Similar to the MW field, non-existent runoff from the CT field during spring 2000 also did not have any measurable nutrient loss. There was also no consistent relationship between the amount of runoff and nutrient losses for other years from either the CT or ZT fields. During this study, nutrient loads were within a varied range of values reported in other studies (Pierson *et al.* 2001, Nash *et al.* 2000, Sharpley *et al.* 1992, McIssac *et al.* 1983, Gross *et al.* 1990). However, conditions from these studies also varied from cattle grazing areas in Australia, tobacco row cropping to turfgrasses. Areal nutrient loads (kg ha^{-1}) from spring runoff at South Tobacco Creek sites were lower than those reported by Tokarz *et al.* (1979) for hog manure applications on experimental plots at the University of Manitoba's Glenlea Research Station during 1976 - 1978. This was understandable since their hog manure application rates (250 and 500 kg N ha^{-1}) in fall were higher than used on the MW field in this study. Their data did show a similar situation to this study whereby nutrient loads were generally reduced substantially for years with relatively low snowmelt runoff volumes. Nutrient losses reported elsewhere were considered to have been due to different tillage and cropping practices (Eghball and Gilley 1999, Sharpley *et al.* 1992, Mueller *et al.* 1984, McIssac *et al.* 1983) and fertilizer management practices (Whalen and Chang 2001, Gross *et al.* 1990).

The amount of nutrients in the soil during runoff events would have some impact, but at what concentration was not obvious. It was apparent a relatively high value of nitrate-N (*i.e.,* 147 kg ha^{-1}) in the upper 15 cm of soil for the MW field during the fall of 1997 combined with an adequate spring runoff volume during 1998 produced losses that were relatively high compared to non-manured fields. Without adequate runoff, similar or higher soil/manure nutrient concentrations in subsequent years generated little loss, or at least none that could be measured.

Green and Turner (1999, 2000) also considered one possible explanation for the high nutrient loss from the MW field compared to the Twin Watershed sites in 1998 might have been due to the difference in size between the study areas. The distance between the outer field boundary opposite the V-notch weir structure of the MW field was less than a third the distance than for the Twin Watershed sites. This shorter distance for the MW field than the Twin Watershed fields may have made it easier for nutrients from all field areas to reach the V-notch weir. Sharpley *et al.* (1992), however, considered that longer slope distances from Southern Plains watersheds allowed for higher sediment related TP than a shorter slope length of corn plots in Wisconsin. The difference between those areas to this study was that most of the TP from the South Tobacco Creek field sites was in the more soluble DP form and less influenced by P adsorbed to soil particles. A shorter slope distance on the MW field may not have been a great advantage either because a slightly greater slope for the Twin Watershed fields would also tend to allow fairly easy movement of runoff from distance points, especially during spring runoff when soils are still partially frozen. Consequently, outer boundary distances on gently sloping fields of sizes used in this study were not thought to be as great a factor as on flatter land.

4.3.3 Precipitation Runoff Events

Post-spring runoff and summer precipitation events large enough to produce measurable runoff at the Twin Watershed weir locations occurred in 1999 and 2000. There were no runoff events from the MW field that produced enough flow to be measurable (Appendices 5c and 5e).

Daily concentrations of TP and TN from the Twin Watershed CT and ZT fields during the summer (July and August) precipitation events were generally between 2.0 – 7.0 mg L^{-1} (Appendices 5c and 5e). These values were similar to daily ranges usually observed during spring runoff, except from the CT field for the spring of 1999 (Appendices 5a – f). Daily TN concentrations from the CT field in spring 1999 were between approximately 12.0 – 24.0 mg L^{-1} and considerably higher than during July (~ 2.0 mg L^{-1}). It was considered that anhydrous ammonia fertilizer spread the preceding fall caused these high nitrogen concentrations the following spring. Likewise, a concentration of approximately 15.0 mg L^{-1} also occurred from the CT field during November 2000 and was considered due to an application of anhydrous ammonia the previous month (Appendix 5e).

Total nutrient losses during spring runoff were usually greater than the overall total loss in the post-spring runoff period mainly because there were more days of runoff in spring. One exception occurred for TP from the CT field during May 22, 1999. The total volume of runoff for this single precipitation event was approximately 67% of the total for the spring runoff period (March 18 - April 7, 1999). The TP concentration on May 22 (~ 0.9 mg L^{-1}) was about double the overall mean value observed during spring runoff. This amount of runoff combined with a relatively high mean TP concentration produced a total off-field TP load (~ 0.44 kg; Appendix 5c) that was more than during the whole spring runoff period (~ 0.32 kg; Appendix 5b). It should be noted, however, that this was a relatively small overall TP loss during spring compared to P losses from the CT or ZT fields for other years (Table 3).

4.4 Comparison of Results Between Laboratories

Paired sample t-test comparisons between samples analyzed at Environment Canada's Laboratory in Saskatoon and Enviro-Test Laboratory in Winnipeg indicated that there were statistical significant differences ($p \leq 0.05$) for ammonia-N, nitrate-nitrite-N and DOC. There were no significant differences for TN, DN, TP, DP, or SS concentrations.

Several split grab samples were collected from the weir structures during spring runoff between 1999 – 2001 to test for differences between water samples sent to the two different laboratories. Water samples collected from the FF and sampling sites on the receiving drainage channels downstream of the field weir structures could not be analyzed at the laboratory in Saskatoon and were sent to Enviro-Test Laboratory for analyses.

The statistical results indicated that comparison of results for most variables from either laboratory could be made, but caution should be exercised when comparing ammonia-N, nitrate-nitrite-N or DOC. Ammonia-N and DOC values were usually slightly higher from Enviro-Test Laboratory than the Environment Canada Laboratory while the opposite occurred for nitrate-nitrite-N. Differences between the two laboratories for ammonia-N and nitrate-nitrite-N were not totally unexpected since changes can occur fairly rapidly between these species. Nitrite nitrogen and nitrate nitrogen form as oxidation of ammonia-N occurs. Although analyses of samples may have occurred within recommended maximum holding times, variations in the time samples were analyzed may have affected results.

5.0 CONCLUSIONS

1) Soil nitrate-N values from the MW, CT and ZT fields fluctuated between years and did not show any consistent increasing or decreasing trend. The field applied with hog manure had nitrate-N values in fall soil samples ranging from approximately 2 – 6 times higher than fields applied with inorganic fertilizers. Soil N values in the MW field were higher than the other fields for the duration of the study. Application of more manure than needed to this field in most years generally kept soil N values in the upper 60 cm (2 feet) in excess of requirements for the intended crop during most years.

2) The nutrient content of the hog manure from a single source operation was not consistent for all years of the study. Samples from 1995, 1997 and 1998 were relatively consistent, but samples from 1999 and 2000 were not as consistent as the previous years. Basing application rates on the range of nutrient values given in current provincial guidelines for hog producers provides a wide range of application rate estimates that could be fairly different than actual values from an operation.

3) Total phosphorus values in soil samples collected from the MW field during fall showed a consistent, slightly increasing trend with consecutive annual applications of hog manure over a four-year period. Manure is relatively high in P and it was considered that more P was applied than needed to supplement soil residual values because fertilization rates were based upon N values. Total phosphorus values for fall soil samples from the CT and ZT fields were approximately 2 – 6 times lower than the MW field.

4) Deep soil testing in 1998 and 2001 indicated that applying more hog manure than needed to supplement residual soil nitrogen values for annual crop requirements appeared to cause increased downward movement and accumulation of N at measured intervals to a depth of 305 cm. There was evidence that P had moved to depths of 305 cm. The P data was too limited to determine if accumulations actually increased between 1998 and 2001.

5) Fall application of hog manure and incorporation into the soil within 48 – 72 hours did not appear to cause greater FC contributions to spring runoff than non-manure applied fields. Fecal coliform values from the MW field were within ranges of values from the Twin Watershed CT and ZT fields.

6) Concentrations of nutrients and carbon were greater from the MW field than all other study field sites during 1998 when substantive runoff occurred from all fields. Concentrations of nutrients from the MW field were within the ranges from the other fields between 1999 – 2001 because runoff from the MW field in these years was either too small to be measurable or was negligible.

7) The mean concentration of TN from the CT field during spring runoff 1999 was over 16.0 mg L^{-1} and was nearly as high as the maximum mean value of 18. 2 mg L^{-1} from the MW field in 1998. The high value from the CT field was attributed to an application of anhydrous ammonia the previous fall.

8) Mean TP concentrations from land runoff were usually < 2.0 mg L^{-1}. Higher mean values of approximately 2.3 mg L^{-1} and 2.7 mg L^{-1} occurred from the MW field and ZT field during 1998 and 2001, respectively. Mean TP concentrations appeared to be slightly increasing each successive year from the ZT and FF fields.

9) Mean SS concentrations were usually relatively high from the CT field compared to other land runoff values. This was considered due to more surface soil exposure and less protection from lower amounts of organic matter and vegetation residue left on this field compared to other sites.

10) The dissolved form of nutrients and organic carbon comprised the greatest proportion of the total concentrations from all sites sampled.

11) Areal loss (kg ha^{-1}) of nutrients from the MW was relatively high compared to the CT or ZT fields during 1998 when appreciable runoff occurred. Total nitrogen loss from the MW field was approximately 8.63 kg ha^{-1} compared to between 1.72 – 1.77 kg ha^{-1} from the ZT and CT fields during 1998. The higher value from the MW field compared to the CT and ZT fields was considered due to much higher N values in the upper 15 cm and 15 - 60 cm soil profile in the MW field for the spring runoff period. During years of negligible runoff, the loss of nutrients was also negligible from the MW field despite relatively high nitrogen and phosphorus values in the soil compared to the CT and ZT fields.

12) The total nutrient loss from fields during precipitation events in the post-spring runoff period was usually lower than during spring runoff because more days of runoff in spring produced more volume.

13) The MW field was too small to obtain adequate spring runoff events on a consistent basis under natural conditions. Continuation of this type of project to determine loading estimates on a field scale would need a larger field size similar to the Twin Watershed fields. Alternatively, some method such as snow fencing that would capture more snow and enhance the opportunity for runoff may be an option. The MW field was much smaller than the other fields and it would be preferable to have fields as close in size and other characteristics as possible.

6.0 LITERATURE CITED

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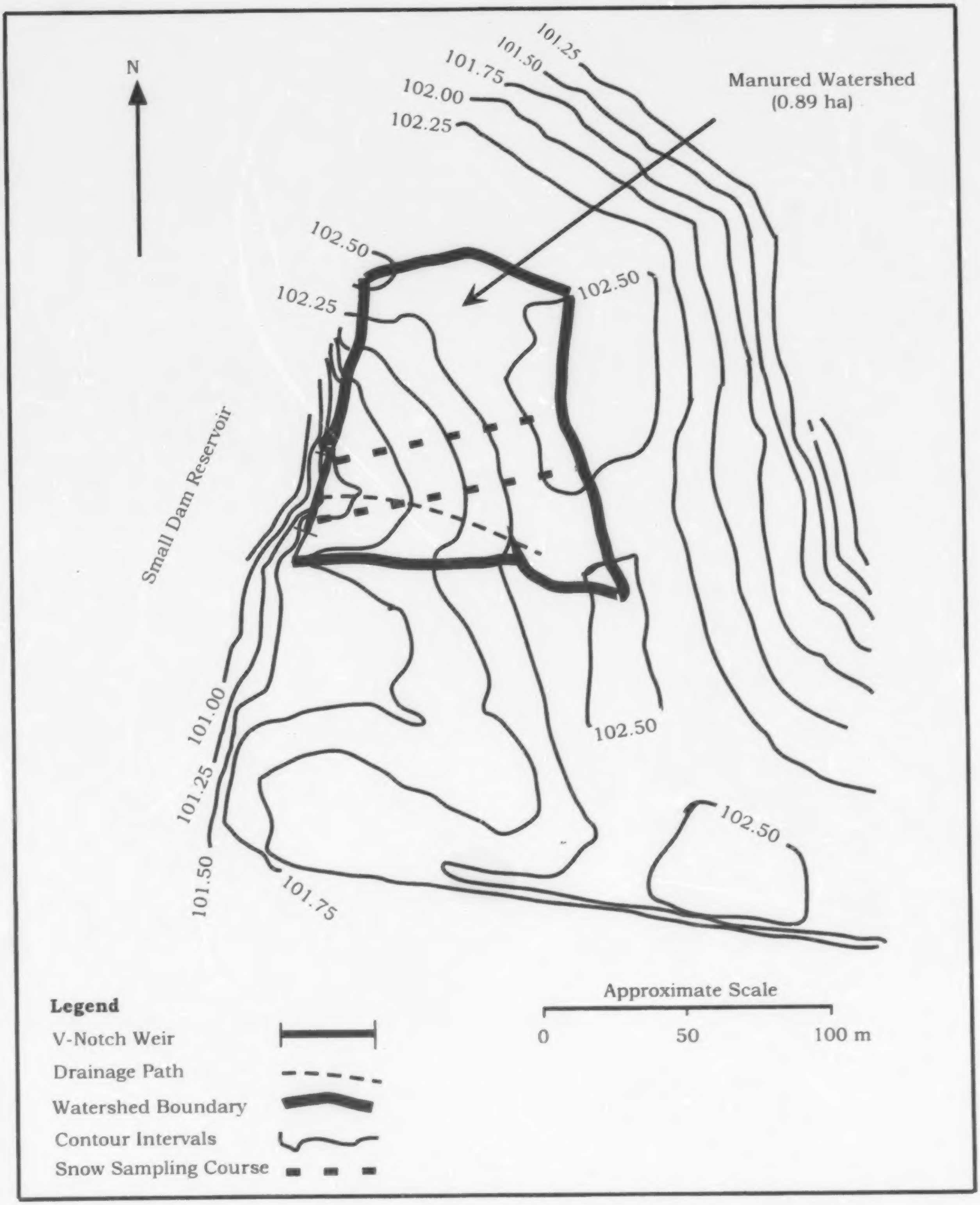
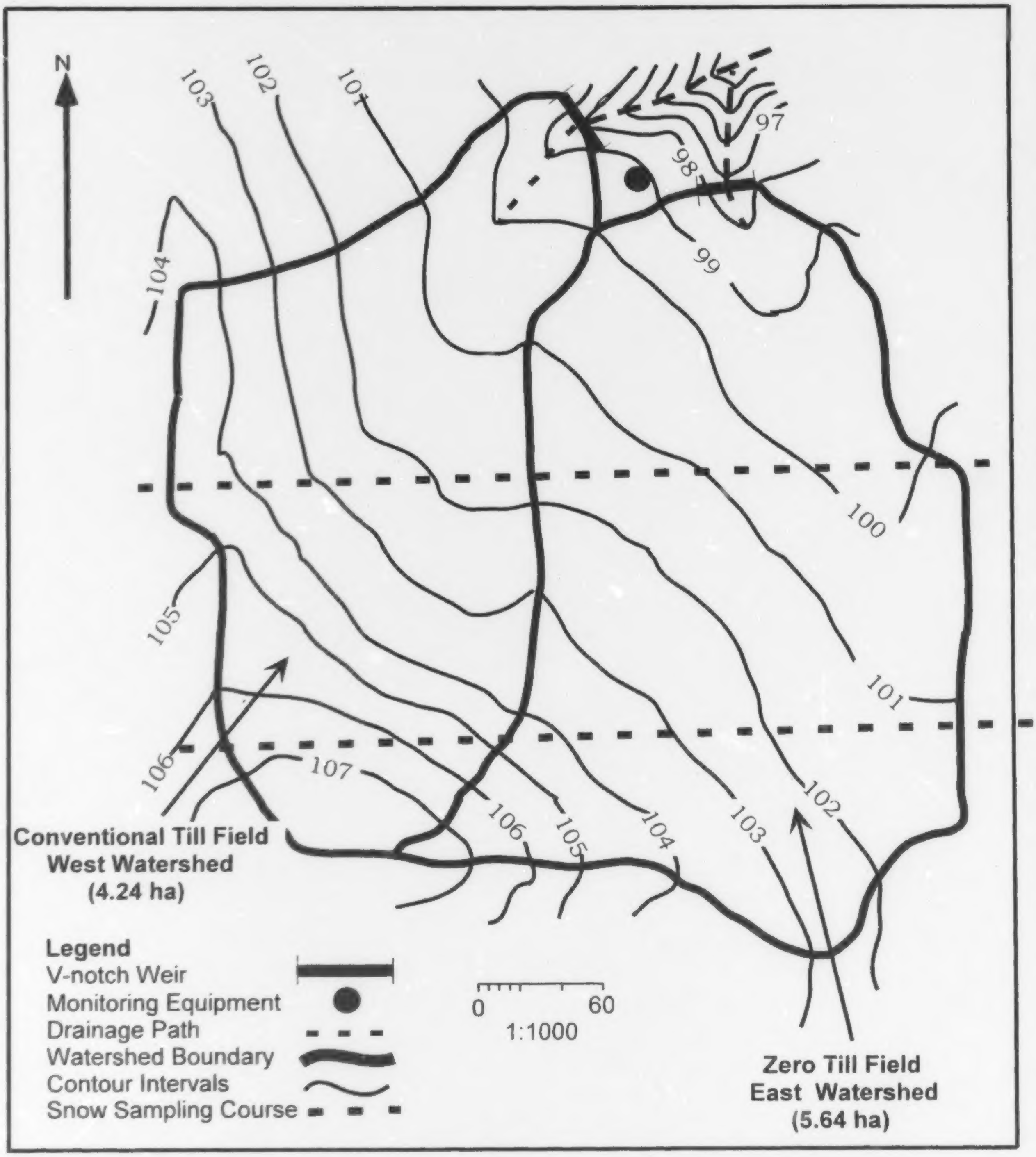
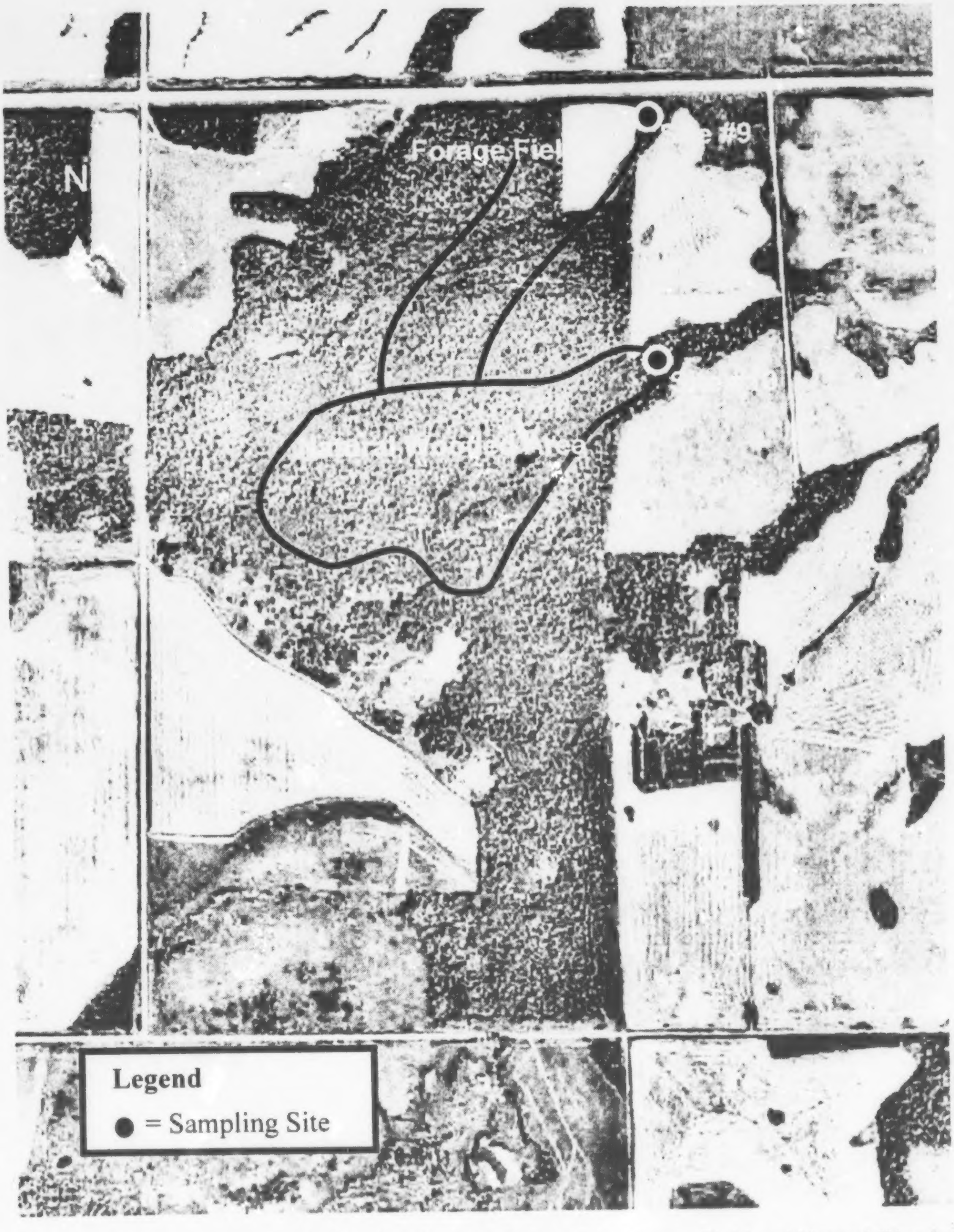
8.0 Appendices



Appendix 1. Contour profile and watershed boundary for the Manured Watershed Field, 1998 - 2001. (Copied from profiles provided by PFRA, Winnipeg 1998).



Appendix 2. Contour profile and watershed boundaries for the Twin Watershed fields, 1998 - 2001. (Copied from profiles provided by PFRA, Winnipeg 1998).



Appendix 3. Orthophotograph showing the boundaries of the Forage Field and Natural Wooded Area sub-watershed units in the South Tobacco Creek Watershed, 1998 - 2001.

Appendix 4. Mean nutritent values for soil samples from the Manured Watershed. Conventional-till and Zero-till fields in the South Tobacco Creek Watershed, 1997 - 2001.

Variable	Profile Depth	Sample Collection Period Fall 1997 kg ha^{-1}	 Fall 1997 (lbs acre^{-1})	 Spring 1998 kg ha^{-1}	 Spring 1998 (lbs acre^{-1})	 Fall 1998 kg ha^{-1}	 Fall 1998 (lbs acre^{-1})	 Fall 1999 kg ha^{-1}	 Fall 1999 (lbs acre^{-1})	 Fall 2000 kg ha^{-1}	 Fall 2000 (lbs acre^{-1})	 Fall 2001 kg ha^{-1}	 Fall 2001 (lbs acre^{-1})
		Manured Watershed*											
Nitrate-N	0 - 15 cm (0-6")	84	(75)	44	(39)	28	(25)	28	(25)	71	(63)	69	(62)
	15 - 60 cm (6 -24")	233	(208)	175	(156)	21	(19)	20	(18)	68	(60)	71	(64)
	Total	317	(283)	218	(195)	49	(44)	48	(43)	139	(123)	140	(124)
Phosphorus	0 - 15 cm (0-6")	73	(65)	134	(120)	86	(77)	93	(83)	108	(96)	134	(120)
	15 - 60 cm (6 -24")	43	(38)	27	(24)	48	(43)	41	(36)	41	(36)	47	(42)
	Total	115	(103)	161	(144)	134	(120)	134	(119)	149	(132)	181	(162)
		Conventional-till Field (West Weir) **											
Nitrate-N	0 - 15 cm (0-6")	13	(12)			0.8	(0.7)	9	(8)	13	(12)	15	(14)
	15 - 60 cm (6 -24")	13	(12)			3	(2.7)	7	(6)	4	(3)	7	(6)
	Total	26	(24)			3.7	(3.3)	16	(14)	17	(15)	22	(20)
Phosphorus	0 - 15 cm (0-6")	29	(26)			16	(14)	21	(20)	16	(14)	23	(21)
	15 - 60 cm (6 -24")					30	(27)	27	(24)	27	(24)	34	(30)
	Total					46	(41)	48	(44)	43	(38)	57	(51)
		Zero-till Field (East Weir) **											
Nitrate-N	0 - 15 cm (0-6")	11	(10)			2.4	(2.2)	13	(12)	9	(8)	13	(12)
	15 - 60 cm (6 -24")	13	(12)			3	(2.7)	13	(12)	4	(3)	6	(5)
	Total	25	(22)			5.4	(4.8)	27	(24)	13	(11)	19	(17)
Phosphorus	0 - 15 cm (0-6")	47	(42)			24	(21)	36	(32)	36	(32)	34	(30)
	15 - 60 cm (6 -24")					30	(27)	34	(30)	34	(30)	34	(30)
	Total					54	(48)	70	(62)	70	(62)	68	(60)

Blanks = No data.

* = Represents the mean value of aggregate samples from each area of an upper, mid, and lower section of the field. Three soil samples were taken from each area to provide an aggregate sample.

** = Value represents an aggregate of three soil samples collected from the field.

Imperial measurements provided for convenience but conversion between metric and imperial units may not be precise because of rounding off.

Appendix 5a. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till. and Zero-till fields during spring runoff, 1998.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})
March 25/98	56	**2.590**	0.145	**2.570**	0.144	**14.375**	0.805	**2.030**	0.114	**10.560**	0.591
March 26/98	54	2.590	0.140	2.570	0.139	14.375	0.776	2.030	0.110	10.560	0.570
March 27/98	224	2.993	0.670	2.577	0.577	17.869	4.003	2.913	0.653	12.733	2.852
March 28/98	51	1.950	0.099	1.860	0.095	19.351	0.987	2.970	0.151	14.000	0.714
March 29/98	32	1.397	0.045	1.180	0.038	20.972	0.671	1.694	0.054	15.367	0.492
March 30/98	11	**1.397**	0.015	**1.180**	0.013	**20.972**	0.231	**1.694**	0.019	**15.367**	0.169
Totals	**428**		**1.115**		**1.006**		**7.473**		**1.100**		**5.389**
	Twin Waterhed Conventional-till Field (West Weir)										
March 26/98	690	0.140	0.097	0.119	0.082	2.653	1.831	0.764	0.527	1.457	1.005
March 27/98	1561	0.222	0.347	0.140	0.219	1.639	2.558	0.316	0.493	0.574	0.896
March 28/98	485	0.462	0.224	0.260	0.126	2.863	1.389	0.180	0.087	0.722	0.350
March 29/98	296	0.646	0.191	0.403	0.119	3.555	1.052	0.205	0.061	1.180	0.349
March 30/98	122	0.604	0.074	0.424	0.052	4.134	0.504	0.378	0.046	1.943	0.237
March 31/98	46	**0.604**	0.028	**0.424**	0.020	**4.134**	0.190	**0.378**	0.017	**1.943**	0.089
Totals	**3200**		**0.960**		**0.617**		**7.524**		**1.232**		**2.927**
	Twin Watershed Zero-till Field (East Weir)										
March 23/98	**< 1**	0.673	**< 0.001**	0.879	**< 0.001**	4.134	**< 0.001**	1.180	**< 0.001**	1.850	**< 0.001**
March 26/98	934	0.151	0.141	0.137	0.128	2.793	2.609	1.160	1.083	1.164	1.087
March 27/98	1880	0.253	0.476	0.179	0.337	1.435	2.698	0.511	0.961	0.358	0.673
March 28/98	800	0.779	0.623	0.592	0.474	2.224	1.779	0.992	0.794	0.266	0.213
March 29/98	447	1.046	0.468	0.914	0.409	3.124	1.396	0.728	0.325	0.704	0.315
March 30/98	267	1.010	0.270	0.866	0.231	3.226	0.861	0.575	0.154	1.060	0.283
March 31/98	69	0.718	0.050	0.814	0.056	4.806	0.332	0.867	0.060	2.180	0.150
Totals	**4397**		**2.027**		**1.634**		**9.675**		**3.376**		**2.721**

Shaded area = measured data miniscule and best estimate used.

Shading shows where water quality data not available and data from the previous or following day used in estimates.

Appendix 5a. Runoff volumes and nutrient loads from the Manured Watershed, Conventional-till, and Zero-till fields during spring runoff, 1998.

Date	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})
	Manured Watershed										
March 25/98	56	**2.590**	0.145	**2.570**	0.144	**14.375**	0.805	**2.030**	0.114	**10.560**	0.591
March 26/98	54	2.590	0.140	2.570	0.139	14.375	0.776	2.030	0.110	10.560	0.570
March 27/98	224	2.993	0.670	2.577	0.577	17.869	4.003	2.913	0.653	12.733	2.852
March 28/98	51	1.950	0.099	1.860	0.095	19.351	0.987	2.970	0.151	14.000	0.714
March 29/98	32	1.397	0.045	1.180	0.038	20.972	0.671	1.694	0.054	15.367	0.492
March 30/98	11	**1.397**	0.015	**1.180**	0.013	**20.972**	0.231	**1.694**	0.019	**15.367**	0.169
Totals	**428**		**1.115**		**1.006**		**7.473**		**1.100**		**5.389**
	Twin Waterhed Conventional-till Field (West Weir)										
March 26/98	690	0.140	0.097	0.119	0.082	2.653	1.831	0.761	0.527	1.457	1.005
March 27/98	1561	0.222	0.347	0.140	0.219	1.639	2.558	0.316	0.493	0.574	0.896
March 28/98	485	0.462	0.224	0.260	0.126	2.863	1.389	0.180	0.087	0.722	0.350
March 29/98	296	0.646	0.191	0.403	0.119	3.555	1.052	0.205	0.061	1.180	0.349
March 30/98	122	0.604	0.074	0.424	0.052	4.134	0.504	0.378	0.046	1.943	0.237
March 31/98	46	**0.604**	0.028	**0.424**	0.020	**4.134**	0.190	**0.378**	0.017	**1.943**	0.089
Totals	**3200**		**0.960**		**0.617**		**7.524**		**1.232**		**2.927**
	Twin Watershed Zero-till Field (East Weir)										
March 23/98	**< 1**	0.673	**< 0.001**	0.879	**< 0.001**	4.134	**< 0.001**	1.180	**< 0.001**	1.850	**< 0.001**
March 26/98	934	0.151	0.141	0.137	0.128	2.793	2.609	1.160	1.083	1.164	1.087
March 27/98	1880	0.253	0.476	0.179	0.337	1.435	2.698	0.511	0.961	0.358	0.673
March 28/98	800	0.779	0.623	0.592	0.474	2.224	1.779	0.992	0.794	0.266	0.213
March 29/98	447	1.046	0.468	0.914	0.409	3.124	1.396	0.728	0.325	0.704	0.315
March 30/98	267	1.010	0.270	0.866	0.231	3.226	0.861	0.575	0.154	1.060	0.283
March 31/98	69	0.718	0.050	0.814	0.056	4.806	0.332	0.867	0.060	2.180	0.150
Totals	**4397**		**2.027**		**1.634**		**9.675**		**3.376**		**2.721**

Shaded area = measured data miniscule and best estimate used.

Shading shows where water quality data not available and data from the previous or following day used in estimates.

Appendix 5b. Runoff volumes and nutrient loads from the Manured Watershed field, Conventinal-till, and Zero-till fields during spring runoff, 1999.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)
Mar 15/99	6.27	0.613	0.004	0.473	0.003	3.420	0.021	1.142	0.007	1.295	0.008
Mar 16/99	1.48	1.200	0.002	1.000	0.001	4.070	0.006	1.050	0.002	1.090	0.002
Totals	7.75		**0.006**		**0.004**		**0.027**		**0.009**		**0.010**
	Twin Waterhed Conventional-till Field (West Weir)										
March 18/99	72	**0.390**	0.028	**0.308**	0.022	**12.680**	0.908	**0.391**	0.028	**10.500**	0.752
March 19/99	46	0.390	0.018	0.308	0.014	12.680	0.579	0.391	0.018	10.500	0.480
March 20/99	169	0.663	0.112	0.518	0.088	18.050	3.058	0.299	0.051	14.900	2.524
March 21/99	119	0.527	0.063	0.425	0.051	16.140	1.927	0.238	0.028	14.100	1.684
March 22/99	91	0.648	0.059	0.372	0.034	17.275	1.575	0.289	0.026	13.400	1.222
March 23/99	55	0.676	0.037	0.499	0.028	17.440	0.966	0.827	0.046	7.190	0.398
March 24/99	41	**0.586**	0.024	**0.427**	0.018	**17.875**	0.733	**0.573**	0.023	**11.545**	0.473
March 25/99	45	0.495	0.022	0.355	0.016	18.310	0.815	0.318	0.014	15.900	0.708
March 26/99	42	0.626	0.027	0.351	0.015	15.380	0.652	0.234	0.010	12.900	0.547
April 07/99	70	0.471	0.033	0.192	0.013	24.585	1.709	0.188	0.013	21.300	1.480
Totals	**750**		**0.318**		**0.236**		**9.014**		**0.197**		**7.060**
	Twin Watershed Zero-till Field (East Weir)										
March 15/99	34	**1.136**	0.038	**1.010**	0.034	**5.900**	0.198	**0.787**	0.026	**2.705**	0.091
March 16/99	113	1.136	0.128	1.010	0.114	5.900	0.664	0.787	0.089	2.705	0.305
March 17/99	1	**0.798**	0.001	**0.698**	0.001	**4.373**	0.004	**0.664**	0.001	**2.030**	0.002
March 19/99	373	0.461	0.172	0.385	0.143	2.845	1.060	0.542	0.202	1.355	0.505
March 20/99	635	0.547	0.347	0.496	0.315	2.720	1.727	0.286	0.182	1.330	0.845
March 21/99	305	0.646	0.197	0.522	0.159	3.650	1.115	0.233	0.071	2.040	0.623
March 22/99	225	0.668	0.151	0.516	0.116	3.980	0.897	0.182	0.041	2.155	0.486
March 23/99	25	0.766	0.019	0.615	0.015	7.670	0.189	0.696	0.017	5.400	0.133
March 24/99	73	**0.660**	0.048	**0.532**	0.039	**6.385**	0.467	**0.506**	0.037	**4.380**	0.321
March 25/99	61	0.554	0.034	0.448	0.027	5.100	0.311	0.316	0.019	3.360	0.205
March 26/99	79	0.508	0.040	0.397	0.031	3.910	0.308	0.240	0.019	2.260	0.178
April 07/99	651	0.659	0.429	0.469	0.305	5.918	3.854	0.252	0.164	3.776	2.459
April 08/99	19	**0.659**	0.013	**0.469**	0.009	**5.918**	0.114	**0.252**	0.005	**3.776**	0.072
Totals	**2594**		**0.845**		**0.732**		**4.571**		**0.544**		**2.279**

Shading shows where water quality data not available. Estimates were based upon data from the previous or following day if needed at the beginning or end of the runoff period and a mean of the previous and following day was used for the remaining situations.

Appendix 5c. Runoff volumes and nutrient loads from the Manured Watershed, Conventional-till, and Zero-till fields during post-spring runoff and summer precipitation events, 1999.

Date	Runoff Volume (m3)	Total Phosphorus Mean Concentration (mg L^{-1})	Total Phosphorus Load (kg day^{-1})	Dissolved Phosphorus Mean Concentration (mg L^{-1})	Dissolved Phosphorus Load (kg day^{-1})	Total Nitrogen Mean Concentration (mg L^{-1})	Total Nitrogen Load (kg day^{-1})	Ammonia Nitrogen Mean Concentration (mg L^{-1})	Ammonia Nitrogen Load (kg day^{-1})	Nitrate-nitrite Nitrogen Mean Concentration (mg L^{-1})	Nitrate-nitrite Nitrogen Load (kg day^{-1})
Manured Watershed											
May 22/99	ND*	2.660	ND	2.220	ND	7.260	ND	0.142	ND	2.270	ND

ND = No data.

*** Note: Runoff volume too small for instrumentation to measure flow. Only a water quality grab sample obtained.**

Date	Runoff Volume (m3)	Total Phosphorus Mean Concentration (mg L^{-1})	Total Phosphorus Load (kg day^{-1})	Dissolved Phosphorus Mean Concentration (mg L^{-1})	Dissolved Phosphorus Load (kg day^{-1})	Total Nitrogen Mean Concentration (mg L^{-1})	Total Nitrogen Load (kg day^{-1})	Ammonia Nitrogen Mean Concentration (mg L^{-1})	Ammonia Nitrogen Load (kg day^{-1})	Nitrate-nitrite Nitrogen Mean Concentration (mg L^{-1})	Nitrate-nitrite Nitrogen Load (kg day^{-1})
Twin Waterhed Conventional-till Field (West Weir)											
May 22/99	500	0.872	0.436	0.116	0.058	7.445	3.723	0.172	0.086	0.275	0.138
July 13/99	8	**0.432**	0.003	**0.213**	0.002	**2.015**	0.016	**0.080**	0.001	**0.220**	0.002
July 15/99	125	0.432	0.054	0.213	0.027	2.015	0.252	0.080	0.010	0.220	0.028
Totals	**133**		**0.057**		**0.028**		**0.268**		**0.011**		**0.029**
Twin Watershed Zero-till Field (East Weir)											
May 22/99	140	2.900	0.406	1.730	0.242	26.550	3.717	5.460	0.764	14.800	2.072
July 08/99	43	**0.892**	0.038	**0.567**	0.024	**3.977**	0.171	**0.249**	0.011	**0.973**	0.042
July 13/99	53	0.892	0.047	0.567	0.030	3.977	0.211	0.249	0.013	0.973	0.052
July 15/99	178	1.000	0.178	0.692	0.123	2.232	0.397	0.166	0.030	0.546	0.097
Totals (Excludes July 8)	**274**		**0.264**		**0.178**		**0.779**		**0.053**		**0.191**

Shading = water samples were not collected from the Conventional-till or Zero-till fields on July 13 and July 8, respectively. Values from the nearest following day used

Appendix 5b. Runoff volumes and nutrient loads from the Manured Watershed field, Conventinal-till, and Zero-till fields during spring runoff, 1999.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)
Mar 15/99	6.27	0.613	0.004	0.473	0.003	3.420	0.021	1.142	0.007	1.295	0.008
Mar 16/99	1.48	1.200	0.002	1.000	0.001	4.070	0.006	1.050	0.002	1.090	0.002
Totals	**7.75**		**0.006**		**0.004**		**0.027**		**0.009**		**0.010**
	Twin Waterhed Conventional-till Field (West Weir)										
March 18/99	72	**0.390**	0.028	**0.308**	0.022	**12.680**	0.908	**0.391**	0.028	**10.500**	0.752
March 19/99	46	0.390	0.018	0.308	0.014	12.680	0.579	0.391	0.018	10.500	0.480
March 20/99	169	0.663	0.112	0.518	0.088	18.050	3.058	0.299	0.051	14.900	2.524
March 21/99	119	0.527	0.063	0.425	0.051	16.140	1.927	0.238	0.028	14.100	1.684
March 22/99	91	0.648	0.059	0.372	0.034	17.275	1.575	0.289	0.026	13.400	1.222
March 23/99	55	0.676	0.037	0.499	0.028	17.440	0.966	0.827	0.046	7.190	0.398
March 24/99	41	**0.586**	0.024	**0.427**	0.018	**17.875**	0.733	**0.573**	0.023	**11.545**	0.473
March 25/99	45	0.495	0.022	0.355	0.016	18.310	0.815	0.318	0.014	15.900	0.708
March 26/99	42	0.626	0.027	0.351	0.015	15.380	0.652	0.234	0.010	12.900	0.547
April 07/99	70	0.471	0.033	0.192	0.013	24.585	1.709	0.188	0.013	21.300	1.480
Totals	**750**		**0.318**		**0.236**		**9.014**		**0.197**		**7.060**
	Twin Watershed Zero-till Field (East Weir)										
March 15/99	34	**1.136**	0.038	**1.010**	0.034	**5.900**	0.198	**0.787**	0.026	**2.705**	0.091
March 16/99	113	1.136	0.128	1.010	0.114	5.900	0.664	0.787	0.089	2.705	0.305
March 17/99	1	**0.798**	0.001	**0.698**	0.001	**4.373**	0.004	**0.664**	0.001	**2.030**	0.002
March 19/99	373	0.461	0.172	0.385	0.143	2.845	1.060	0.542	0.202	1.355	0.505
March 20/99	635	0.547	0.347	0.496	0.315	2.720	1.727	0.286	0.182	1.330	0.845
March 21/99	305	0.646	0.197	0.522	0.159	3.650	1.115	0.233	0.071	2.040	0.623
March 22/99	225	0.668	0.151	0.516	0.116	3.980	0.897	0.182	0.041	2.155	0.486
March 23/99	25	0.766	0.019	0.615	0.015	7.670	0.189	0.696	0.017	5.400	0.133
March 24/99	73	**0.660**	0.048	**0.532**	0.039	**6.385**	0.467	**0.506**	0.037	**4.380**	0.321
March 25/99	61	0.554	0.034	0.448	0.027	5.100	0.311	0.316	0.019	3.360	0.205
March 26/99	79	0.508	0.040	0.397	0.031	3.910	0.308	0.240	0.019	2.260	0.178
April 07/99	651	0.659	0.429	0.469	0.305	5.918	3.854	0.252	0.164	3.776	2.459
April 08/99	19	**0.659**	0.013	**0.469**	0.009	**5.918**	0.114	**0.252**	0.005	**3.776**	0.072
Totals	**2594**		**0.845**		**0.732**		**4.571**		**0.544**		**2.279**

Shading shows where water quality data not available. Estimates were based upon data from the previous or following day if needed at the beginning or end of the runoff period and a mean of the previous and following day was used for the remaining situations.

Appendix 5c. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till. and Zero-till fields during post-spring runoff and summer precipitation events. 1999.

Date	Runoff Volume (m3)	Total Phosphorus Mean Concentration (mg L^{-1})	Total Phosphorus Load (kg day^{-1})	Dissolved Phosphorus Mean Concentration (mg L^{-1})	Dissolved Phosphorus Load (kg day^{-1})	Total Nitrogen Mean Concentration (mg L^{-1})	Total Nitrogen Load (kg day^{-1})	Ammonia Nitrogen Mean Concentration (mg L^{-1})	Ammonia Nitrogen Load (kg day^{-1})	Nitrate-nitrite Nitrogen Mean Concentration (mg L^{-1})	Nitrate-nitrite Nitrogen Load (kg day^{-1})
Manured Watershed											
May 22/99	ND*	2.660	ND	2.220	ND	7.260	ND	0.142	ND	2.270	ND

ND = No data.

*** Note: Runoff volume too small for instrumentation to measure flow. Only a water quality grab sample obtained.**

Date	Runoff Volume (m3)	Total Phosphorus Mean Concentration (mg L^{-1})	Total Phosphorus Load (kg day^{-1})	Dissolved Phosphorus Mean Concentration (mg L^{-1})	Dissolved Phosphorus Load (kg day^{-1})	Total Nitrogen Mean Concentration (mg L^{-1})	Total Nitrogen Load (kg day^{-1})	Ammonia Nitrogen Mean Concentration (mg L^{-1})	Ammonia Nitrogen Load (kg day^{-1})	Nitrate-nitrite Nitrogen Mean Concentration (mg L^{-1})	Nitrate-nitrite Nitrogen Load (kg day^{-1})
Twin Waterhed Conventional-till Field (West Weir)											
May 22/99	500	0.872	0.436	0.116	0.058	7.445	3.723	0.172	0.086	0.275	0.138
July 13/99	8	**0.432**	0.003	**0.213**	0.002	**2.015**	0.016	**0.080**	0.001	**0.220**	0.002
July 15/99	125	0.432	0.054	0.213	0.027	2.015	0.252	0.080	0.010	0.220	0.028
Totals	**133**		**0.057**		**0.028**		**0.268**		**0.011**		**0.029**
Twin Watershed Zero-till Field (East Weir)											
May 22/99	140	2.900	0.406	1.730	0.242	26.550	3.717	5.460	0.764	14.800	2.072
July 08/99	43	**0.892**	0.038	**0.567**	0.024	**3.977**	0.171	**0.249**	0.011	**0.973**	0.042
July 13/99	53	0.892	0.047	0.567	0.030	3.977	0.211	0.249	0.013	0.973	0.052
July 15/99	178	1.000	0.178	0.692	0.123	2.232	0.397	0.166	0.030	0.546	0.097
Totals (Excludes July 8)	**274**		**0.264**		**0.178**		**0.779**		**0.053**		**0.191**

Shading = water samples were not collected from the Conventional-till or Zero-till fields on July 13 and July 8, respectively. Values from the nearest following day used.

Appendix 5d. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till and Zero-till fields during spring runoff, 2000.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})
	Runoff negligible and too small to collect water samples or to be measurable.										
Totals											
	Twin Waterhed Conventional-till Field (West Weir)										
	Runoff negligible and too small to collect water samples or to be measurable.										
Totals											
	Twin Watershed Zero-till Field (East Weir)										
Feb 22/00	391	1.337	0.523	1.237	0.484	4.326	1.691	0.221	0.086	2.437	0.953
Feb 23/00	146	1.500	0.219	1.370	0.200	5.824	0.850	0.105	0.015	3.685	0.538
Feb 25/00	635	1.663	1.056	1.573	0.999	8.319	5.283	0.202	0.128	5.987	3.802
Feb 26/00	429	1.840	0.789	1.740	0.746	6.747	2.894	0.129	0.055	4.895	2.100
Feb 27/00	129	**1.840**	0.237	**1.740**	0.224	**6.747**	0.870	**0.129**	0.017	**4.895**	0.631
Feb 28/00	90	**1.840**	0.166	**1.740**	0.157	**6.747**	0.607	**0.129**	0.012	**4.895**	0.441
Feb 29/00	52	**1.840**	0.096	**1.740**	0.090	**6.747**	0.351	**0.129**	0.007	**4.895**	0.255
Totals	**1872**		**2.467**		**2.326**		**10.505**		**0.227**		**7.512**

Shading shows where water quality data not available and data for the last day with actual data used for estimates.

Appendix 5e. Runoff volumes and nutrient loads from the Manured Watershed, Conventional-till and Zero-till fields during post-spring runoff and summer precipitation events, 2000.

Date	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})
	Manured Watershed										
	Runoff negligible and too small to collect water samples or to be measured.										
Totals											
	Twin Waterhed Conventional-till Field (West Weir)										
Aug 5/00	4	**1.565**	0.006	**0.869**	0.003	**7.970**	0.032	**0.300**	0.001	**2.175**	0.009
Aug 11/00	97	1.565	0.152	0.869	0.084	7.970	0.773	0.300	0.029	2.175	0.211
Sep 6/00	26	0.652	0.017	0.616	0.016	5.740	0.149	0.321	0.008	2.720	0.071
Nov 1/00	31	1.880	0.058	1.627	0.050	15.510	0.481	1.326	0.041	9.747	0.302
Totals	**158**		**0.233**		**0.154**		**1.435**		**0.080**		**0.593**
	Twin Watershed Zero-till Field (East Weir)										
Aug 5/00	14	**1.622**	0.023	**1.306**	0.018	**5.263**	0.074	**0.282**	0.004	**2.178**	0.030
Aug 11/00	98	1.622	0.159	1.306	0.128	5.263	0.516	0.282	0.028	2.178	0.213
Sep 6/00	65	1.400	0.091	1.144	0.074	5.971	0.388	0.302	0.020	2.490	0.162
Nov 1/00	118	1.686	0.199	1.552	0.183	3.313	0.391	0.303	0.036	0.694	0.082
Totals (Excludes July 8)	**295**		**0.472**		**0.404**		**1.368**		**0.087**		**0.488**

Shading = water samples were not collected from the Conventional-till field weir or Zero-till field weir on August 5 and values for August 11 have been used.

Appendix 5d. Runoff volumes and nutrient loads from the Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 2000.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)
	Runoff negligible and too small to collect water samples or to be measurable.										
Totals											
	Twin Waterhed Conventional-till Field (West Weir)										
	Runoff negligible and too small to collect water samples or to be measurable.										
Totals											
	Twin Watershed Zero-till Field (East Weir)										
Feb 22/00	391	1.337	0.523	1.237	0.484	4.326	1.691	0.221	0.086	2.437	0.953
Feb 23/00	146	1.500	0.219	1.370	0.200	5.824	0.850	0.105	0.015	3.685	0.538
Feb 25/00	635	1.663	1.056	1.573	0.999	8.319	5.283	0.202	0.128	5.987	3.802
Feb 26/00	429	1.840	0.789	1.740	0.746	6.747	2.894	0.129	0.055	4.895	2.100
Feb 27/00	129	**1.840**	0.237	**1.740**	0.224	**6.747**	0.870	**0.129**	0.017	**4.895**	0.631
Feb 28/00	90	**1.840**	0.166	**1.740**	0.157	**6.747**	0.607	**0.129**	0.012	**4.895**	0.441
Feb 29/00	52	**1.840**	0.096	**1.740**	0.090	**6.747**	0.351	**0.129**	0.007	**4.895**	0.255
Totals	**1872**		**2.467**		**2.326**		**10.505**		**0.227**		**7.512**

Shading shows where water quality data not available and data for the last day with actual data used for estimates.

Appendix 5e. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till and Zero-till fields during post-spring runoff and summer precipitation events. 2000.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m3)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)	Mean Concentration (mg L⁻¹)	Load (kg day⁻¹)
	Runoff negligible and too small to collect water samples or to be measured.										
Totals											
	Twin Waterhed Conventional-till Field (West Weir)										
Aug 5/00	4	**1.565**	0.006	**0.869**	0.003	**7.970**	0.032	**0.300**	0.001	**2.175**	0.009
Aug 11/00	97	1.565	0.152	0.869	0.084	7.970	0.773	0.300	0.029	2.175	0.211
Sep 6/00	26	0.652	0.017	0.616	0.016	5.740	0.149	0.321	0.008	2.720	0.071
Nov 1/00	31	1.880	0.058	1.627	0.050	15.510	0.481	1.326	0.041	9.747	0.302
Totals	**158**		**0.233**		**0.154**		**1.435**		**0.080**		**0.593**
	Twin Watershed Zero-till Field (East Weir)										
Aug 5/00	14	**1.622**	0.023	**1.306**	0.018	**5.263**	0.074	**0.282**	0.004	**2.178**	0.030
Aug 11/00	98	1.622	0.159	1.306	0.128	5.263	0.516	0.282	0.028	2.178	0.213
Sep 6/00	65	1.400	0.091	1.144	0.074	5.971	0.388	0.302	0.020	2.490	0.162
Nov 1/00	118	1.686	0.199	1.552	0.183	3.313	0.391	0.303	0.036	0.694	0.082
Totals (Excludes July 8)	**295**		**0.472**		**0.404**		**1.368**		**0.087**		**0.488**

Shading = water samples were not collected from the Conventional-till field weir or Zero-till field weir on August 5 and values for August 11 have been used

Appendix 5f. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till and Zero-till fields during spring runoff, 2001.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
		Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load
	(m^3)	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})
Mar 16/01	0.34	0.995	< 0.001	0.89	< 0.001	2.34	0.001	**0.37**	< 0.001	0.58	< 0.001
Mar 17/01	1.67	0.995	0.002	0.89	0.001	2.34	0.004	**0.37**	0.001	0.58	0.001
Mar 18/01	0.12	0.995	< 0.001	0.89	< 0.001	2.34	< 0.001	**0.37**	< 0.001	0.58	< 0.001
Mar 19/01	0.04	0.995	< 0.001	0.89	< 0.001	2.34	< 0.001	**0.37**	< 0.001	0.58	< 0.001
Mar 20/01	9.10	0.995	0.009	0.89	0.008	2.34	0.021	**0.37**	0.003	0.58	0.005
Mar 27/01	0.01	**1.010**	< 0.001	0.89	< 0.001	**2.47**	< 0.001	**0.34**	< 0.001	**0.59**	< 0.001
Mar 28/01	0.06	**1.010**	< 0.001	0.89	< 0.001	**2.47**	< 0.001	**0.34**	< 0.001	**0.59**	< 0.001
Mar 29/01	3.60	**1.020**	0.004	**0.88**	0.003	**2.60**	0.009	**0.30**	0.001	**0.60**	0.002
Mar 30/01	4.04	**0.853**	0.003	**0.69**	0.003	**3.44**	0.014	**0.30**	0.001	**1.46**	0.006
Apr 2/01	1.40	**0.853**	0.001	**0.69**	0.001	**3.44**	0.005	**0.30**	< 0.001	**1.46**	0.002
Apr 3/01	5.80	0.686	0.004	0.59	0.003	4.28	0.025	**0.30**	0.002	**2.31**	0.013
Totals	**26.17**		**0.023**		**0.020**		**0.079**		**0.008**		**0.030**

Shading = laboratory analyses results from Envriro-test Laboratory used.
Volumes rounded to nearest 0.01 m^3 due to small values.

Twin Waterhed
Conventional-till Field (West Weir)

Date	Runoff Volume (m^3)	TP Mean Concentration (mg L^{-1})	TP Load (kg day^{-1})	DP Mean Concentration (mg L^{-1})	DP Load (kg day^{-1})	TN Mean Concentration (mg L^{-1})	TN Load (kg day^{-1})	Ammonia Mean Concentration (mg L^{-1})	Ammonia Load (kg day^{-1})	Nitrate-nitrite Mean Concentration (mg L^{-1})	Nitrate-nitrite Load (kg day^{-1})
Mar 21/01	5	2.430	0.012	2.260	0.011	19.925	0.100	1.92	0.010	14.6	0.073
Mar 28/01	11	**1.890**	0.021	**1.770**	0.019	**14.588**	0.160	**1.29**	0.014	**9.96**	0.110
Mar 29/01	20	1.350	0.027	1.280	0.026	9.250	0.185	**1.29**	0.026	5.31	0.106
Mar 30/01	109	1.120	0.122	0.976	0.106	7.990	0.871	**1.29**	0.141	3.9	0.425
Mar 31/01	0.011	0.981	0.000	1.120	0.000	8.262	0.000	**1.29**	0.000	3.82	0.000
Apr 2/01	25	**0.826**	0.021	**0.870**	0.022	**7.736**	0.193	**1.29**	0.032	**4.08**	0.102
Apr 3/01	267	0.672	0.179	0.620	0.166	7.209	1.925	**1.29**	0.344	4.34	1.159
Apr 4/01	141	0.669	0.094	0.642	0.091	5.061	0.714	**1.29**	0.182	2.47	0.348
Apr 5/01	658	0.674	0.443	0.579	0.381	4.840	3.185	0.669	0.440	2.48	1.632
Apr 6/01	639	0.744	0.475	0.568	0.363	4.220	2.697	0.647	0.413	1.53	0.978
Apr 7/01	150	0.844	0.127	0.795	0.119	5.287	0.793	0.731	0.110	2.94	0.441
Apr 8/01	163	0.978	0.159	0.908	0.148	6.421	1.047	**0.731**	0.119	4.04	0.659
Apr 9/01	97	**2.610**	0.253	**2.480**	0.241	**6.100**	0.592	**0.731**	0.071	**3.24**	0.314
Apr 10/01	58	**2.610**	0.151	**2.480**	0.144	**6.100**	0.354	**0.731**	0.042	**3.24**	0.188
Apr 11/01	53	**2.610**	0.138	**2.480**	0.131	**6.100**	0.323	**0.731**	0.039	**3.24**	0.172
Apr 12/01	47	**2.610**	0.123	**2.480**	0.117	**6.100**	0.287	**0.731**	0.034	**3.24**	0.152
Apr 13/01	63	**2.610**	0.164	**2.480**	0.156	**6.100**	0.384	**0.731**	0.046	**3.24**	0.204
Apr 14/01	71	**2.610**	0.185	**2.480**	0.176	**6.100**	0.433	**0.731**	0.052	**3.24**	0.230
Apr 17/01	53	**2.610**	0.138	**2.480**	0.131	**6.100**	0.323	**0.731**	0.039	**3.24**	0.172
Apr 18/01	35	**2.610**	0.091	**2.480**	0.087	**6.100**	0.214	**0.731**	0.026	**3.24**	0.113
Apr 19/01	11	**2.610**	0.029	**2.480**	0.027	**6.100**	0.067	**0.731**	0.008	**3.24**	0.036
Apr 20/01	122	4.240	0.517	4.060	0.495	5.780	0.705	**0.731**	0.089	2.44	0.298
Total Load	**2798**		**3.472**		**3.157**		**15.551**		**2.277**		**7.911**

Shaded area = measured data miniscule and best estimate used.
Shaded area indicate water quality data not available and these values represent a mean value calculated from actual data of the previous and following days

Appendix 5f continued. Runoff volumes and nutrient loads from the Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 2001.

		Twin Watershed Zero-till Field (East Weir)									
Date	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
		Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load	Mean Concentration	Load
	(m^3)	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})	(mg L^{-1})	(kg day^{-1})
Mar 20/01	99	5.070	0.502	4.800	0.475	13.927	1.379	**2.230**	0.221	7.120	0.705
Mar 21/01	65	4.460	0.290	4.240	0.276	0.731	0.048	2.230	0.145	5.790	0.376
Mar 28/01	5	**3.600**	0.018	**3.350**	0.017	**3.590**	0.018	**1.740**	0.009	**3.760**	0.019
Mar 29/01	114	2.740	0.312	2.500	0.285	6.450	0.735	**1.740**	0.198	1.740	0.198
Mar 30/01	127	2.570	0.326	2.370	0.301	5.470	0.695	**1.740**	0.221	1.560	0.198
Mar 31/01	4	2.380	0.010	2.260	0.009	5.209	0.021	**1.740**	0.007	1.630	0.007
Apr 1/01	1	**2.540**	0.003	**2.470**	0.002	**5.830**	0.006	**1.740**	0.002	**1.810**	0.002
Apr 2/01	38	**2.540**	0.097	**2.470**	0.094	**5.830**	0.222	**1.740**	0.066	**1.810**	0.069
Apr 3/01	144	2.710	0.390	2.680	0.386	6.446	0.928	**1.740**	0.251	1.980	0.285
Apr 4/01	255	2.210	0.564	2.160	0.551	4.999	1.275	**1.740**	0.444	1.480	0.377
Apr 5/01	782	1.670	1.306	1.590	1.243	4.090	3.198	1.260	0.985	1.280	1.001
Apr 6/01	933	1.790	1.670	1.690	1.577	3.213	2.998	1.140	1.064	0.716	0.668
Apr 7/01	159	2.120	0.337	2.020	0.321	5.718	0.909	1.220	0.194	2.695	0.429
Apr 8/01	114	1.620	0.185	1.540	0.176	7.570	0.863	**1.220**	0.139	4.750	0.542
Apr 9/01	68	**3.130**	0.213	**3.010**	0.205	**8.030**	0.546	**1.220**	0.083	**5.070**	0.345
Apr 10/01	55	**3.130**	0.172	**3.010**	0.166	**8.030**	0.442	**1.220**	0.067	**5.070**	0.279
Apr 11/01	31	**3.130**	0.097	**3.010**	0.093	**8.030**	0.249	**1.220**	0.038	**5.070**	0.157
Apr 12/01	49	**3.130**	0.153	**3.010**	0.147	**8.030**	0.393	**1.220**	0.060	**5.070**	0.248
Apr 13/01	25	**3.130**	0.078	**3.010**	0.075	**8.030**	0.201	**1.220**	0.031	**5.070**	0.127
Apr 14/01	79	**3.130**	0.247	**3.010**	0.238	**8.030**	0.634	**1.220**	0.096	**5.070**	0.401
Apr 15/01	24	**3.130**	0.075	**3.010**	0.072	**8.030**	0.193	**1.220**	0.029	**5.070**	0.122
Apr 16/01	31	**3.130**	0.097	**3.010**	0.093	**8.030**	0.249	**1.220**	0.038	**5.070**	0.157
Apr 17/01	22	**3.130**	0.069	**3.010**	0.066	**8.030**	0.177	**1.220**	0.027	**5.070**	0.112
Apr 18/01	22	**3.130**	0.069	**3.010**	0.066	**8.030**	0.177	**1.220**	0.027	**5.070**	0.112
Apr 20/01	47	4.640	0.218	4.475	0.210	8.488	0.399	**1.220**	0.057	5.390	0.253
Total Load	3293		7.498		7.145		16.953		4.498		7.187

Shading shows where water quality data not available. Estimates were based upon data from the previous or following day if needed at the beginning or end of the runoff period and a mean of the nearest previous and following day was used for the remaining situations.

Appendix 5f. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till and Zero-till fields during spring runoff, 2001.

Date	Manured Watershed										
	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m^3)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)	Mean Concentration ($mg\ L^{-1}$)	Load ($kg\ day^{-1}$)
Mar 16/01	0.34	0.995	<0.001	0.89	<0.001	2.34	0.001	**0.37**	<0.001	0.58	<0.001
Mar 17/01	1.67	0.995	0.002	0.89	0.001	2.34	0.004	**0.37**	0.001	0.58	0.001
Mar 18/01	0.12	0.995	<0.001	0.89	<0.001	2.34	<0.001	**0.37**	<0.001	0.58	<0.001
Mar 19/01	0.04	0.995	<0.001	0.89	<0.001	2.34	<0.001	**0.37**	<0.001	0.58	<0.001
Mar 20/01	9.10	0.995	0.009	0.89	0.008	2.34	0.021	**0.37**	0.003	0.58	0.005
Mar 27/01	0.01	**1.010**	<0.001	0.89	<0.001	**2.47**	<0.001	**0.34**	<0.001	**0.59**	<0.001
Mar 28/01	0.06	**1.010**	<0.001	0.89	<0.001	**2.47**	<0.001	**0.34**	<0.001	**0.59**	<0.001
Mar 29/01	3.60	**1.020**	0.004	**0.89**	0.003	**2.60**	0.009	**0.30**	0.001	**0.60**	0.002
Mar 30/01	4.04	**0.853**	0.003	**0.69**	0.003	**3.44**	0.014	**0.30**	0.001	**1.46**	0.006
Apr 2/01	1.40	**0.853**	0.001	**0.69**	0.001	**3.44**	0.005	**0.30**	<0.001	**1.46**	0.002
Apr 3/01	5.80	0.686	0.004	0.59	0.003	4.28	0.025	**0.30**	0.002	**2.31**	0.013
Totals	**26.17**		**0.023**		**0.020**		**0.079**		**0.008**		**0.030**

Shading = laboratory analyses results from Envriro-test Laboratory used.
Volumes rounded to nearest 0.01 m^3 due to small values.

Twin Waterhed
Conventional-till Field (West Weir)

Mar 21/01	5	2.430	0.012	2.260	0.011	19.925	0.100	1.92	0.010	14.6	0.073
Mar 28/01	11	**1.890**	0.021	**1.770**	0.019	**14.588**	0.160	**1.29**	0.014	**9.96**	0.110
Mar 29/01	20	1.350	0.027	1.280	0.026	9.250	0.185	**1.29**	0.026	5.31	0.106
Mar 30/01	109	1.120	0.122	0.976	0.106	7.990	0.871	**1.29**	0.141	3.9	0.425
Mar 31/01	0.011	0.981	0.000	1.120	0.000	8.262	0.000	**1.29**	0.000	3.82	0.000
Apr 2/01	25	**0.826**	0.021	**0.870**	0.022	**7.736**	0.193	**1.29**	0.032	**4.08**	0.102
Apr 3/01	267	0.672	0.179	0.620	0.166	7.209	1.925	**1.29**	0.344	4.34	1.159
Apr 4/01	141	0.669	0.094	0.642	0.091	5.061	0.714	**1.29**	0.182	2.47	0.348
Apr 5/01	658	0.674	0.443	0.579	0.381	4.840	3.185	0.669	0.440	2.48	1.632
Apr 6/01	639	0.744	0.475	0.568	0.363	4.220	2.697	0.647	0.413	1.53	0.978
Apr 7/01	150	0.844	0.127	0.795	0.119	5.287	0.793	0.731	0.110	2.94	0.441
Apr 8/01	163	0.978	0.159	0.908	0.148	6.421	1.047	**0.731**	0.119	4.04	0.659
Apr 9/01	97	**2.610**	0.253	**2.480**	0.241	**6.100**	0.592	**0.731**	0.071	**3.24**	0.314
Apr 10/01	58	**2.610**	0.151	**2.480**	0.144	**6.100**	0.354	**0.731**	0.042	**3.24**	0.188
Apr 11/01	53	**2.610**	0.138	**2.480**	0.131	**6.100**	0.323	**0.731**	0.039	**3.24**	0.172
Apr 12/01	47	**2.610**	0.123	**2.480**	0.117	**6.100**	0.287	**0.731**	0.034	**3.24**	0.152
Apr 13/01	63	**2.610**	0.164	**2.480**	0.156	**6.100**	0.384	**0.731**	0.046	**3.24**	0.204
Apr 14/01	71	**2.610**	0.185	**2.480**	0.176	**6.100**	0.433	**0.731**	0.052	**3.24**	0.230
Apr 17/01	53	**2.610**	0.138	**2.480**	0.131	**6.100**	0.323	**0.731**	0.039	**3.24**	0.172
Apr 18/01	35	**2.610**	0.091	**2.480**	0.087	**6.100**	0.214	**0.731**	0.026	**3.24**	0.113
Apr 19/01	11	**2.610**	0.029	**2.480**	0.027	**6.100**	0.067	**0.731**	0.008	**3.24**	0.036
Apr 20/01	122	4.240	0.517	4.060	0.495	5.780	0.705	**0.731**	0.089	2.44	0.298
Total Load	**2798**		**3.472**		**3.157**		**15.551**		**2.277**		**7.911**

Shaded area = measured data miniscule and best estimate used
Shaded areas indicate water quality data not available and these values represent a mean value calculated from actual data of the previous and following days

Appendix 5f continued. Runoff volumes and nutrient loads from the Manured Watershed. Conventional-till and Zero-till fields during spring runoff, 2001.

		Twin Watershed Zero-till Field (East Weir)									
Date	Runoff Volume	Total Phosphorus		Dissolved Phosphorus		Total Nitrogen		Ammonia Nitrogen		Nitrate-nitrite Nitrogen	
	(m^3)	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})	Mean Concentration (mg L^{-1})	Load (kg day^{-1})
Mar 20/01	99	5.070	0.502	4.800	0.475	13.927	1.379	**2.230**	0.221	7.120	0.705
Mar 21/01	65	4.460	0.290	4.240	0.276	0.731	0.048	2.230	0.145	5.790	0.376
Mar 28/01	5	**3.600**	0.018	**3.350**	0.017	**3.590**	0.018	**1.740**	0.009	**3.760**	0.019
Mar 29/01	114	2.740	0.312	2.500	0.285	6.450	0.735	**1.740**	0.198	1.740	0.198
Mar 30/01	127	2.570	0.326	2.370	0.301	5.470	0.695	**1.740**	0.221	1.560	0.198
Mar 31/01	4	2.380	0.010	2.260	0.009	5.209	0.021	**1.740**	0.007	1.630	0.007
Apr 1/01	1	**2.540**	0.003	**2.470**	0.002	**5.830**	0.006	**1.740**	0.002	**1.810**	0.002
Apr 2/01	38	**2.540**	0.097	**2.470**	0.094	**5.830**	0.222	**1.740**	0.066	**1.810**	0.069
Apr 3/01	144	2.710	0.390	2.680	0.386	6.446	0.928	**1.740**	0.251	1.980	0.285
Apr 4/01	255	2.210	0.564	2.160	0.551	4.999	1.275	**1.740**	0.444	1.480	0.377
Apr 5/01	782	1.670	1.306	1.590	1.243	4.090	3.198	1.260	0.985	1.280	1.001
Apr 6/01	933	1.790	1.670	1.690	1.577	3.213	2.998	1.140	1.064	0.716	0.668
Apr 7/01	159	2.120	0.337	2.020	0.321	5.718	0.909	1.220	0.194	2.695	0.429
Apr 8/01	114	1.620	0.185	1.540	0.176	7.570	0.863	**1.220**	0.139	4.750	0.542
Apr 9/01	68	**3.130**	0.213	**3.010**	0.205	**8.030**	0.546	**1.220**	0.083	**5.070**	0.345
Apr 10/01	55	**3.130**	0.172	**3.010**	0.166	**8.030**	0.442	**1.220**	0.067	**5.070**	0.279
Apr 11/01	31	**3.130**	0.097	**3.010**	0.093	**8.030**	0.249	**1.220**	0.038	**5.070**	0.157
Apr 12/01	49	**3.130**	0.153	**3.010**	0.147	**8.030**	0.393	**1.220**	0.060	**5.070**	0.248
Apr 13/01	25	**3.130**	0.078	**3.010**	0.075	**8.030**	0.201	**1.220**	0.031	**5.070**	0.127
Apr 14/01	79	**3.130**	0.247	**3.010**	0.238	**8.030**	0.634	**1.220**	0.096	**5.070**	0.401
Apr 15/01	24	**3.130**	0.075	**3.010**	0.072	**8.030**	0.193	**1.220**	0.029	**5.070**	0.122
Apr 16/01	31	**3.130**	0.097	**3.010**	0.093	**8.030**	0.249	**1.220**	0.038	**5.070**	0.157
Apr 17/01	22	**3.130**	0.069	**3.010**	0.066	**8.030**	0.177	**1.220**	0.027	**5.070**	0.112
Apr 18/01	22	**3.130**	0.069	**3.010**	0.066	**8.030**	0.177	**1.220**	0.027	**5.070**	0.112
Apr 20/01	47	4.640	0.218	4.475	0.210	8.488	0.399	**1.220**	0.057	5.390	0.253
Total Load	3293		7.498		7.145		16.953		4.498		7.187

Shading shows where water quality data not available. Estimates were based upon data from the previous or following day if needed at the beginning or end of the runoff period and a mean of the nearest previous and following day was used for the remaining situations.

Appendix 6. Snow depths (cm) and water equivelancy depths (cm cm^{-1} snow) from snow course monitoring from the Manured Watershed, Conventional-till and Zero-till fields, 1998 - 2001.

Date (Last sample)	Variable		Manured Watershed Field	Conventional-till Field	Zero-till Field
March 18/98	Snow Depth	(cm)	22.60	24.10	26.60
	Water Equivalency	(cm cm^{-1} of snow)	0.25	0.37	0.36
		(cm of water)	5.65	8.92	9.57
March 15/99	Snow Depth	(cm)	3.60	11.80	15.80
	Water Equivalency	(cm cm^{-1} of snow)	0.54	0.26	0.33
		(cm of water)	1.95	3.01	5.17
April 5/99	Snow Depth	(cm)	16.00	15.00	16.40
	Water Equivalency	(cm cm^{-1} of snow)	0.22	0.29	0.27
		(cm of water)	3.54	4.36	4.44
Total /99	Snow Depth	(cm)	19.60	26.80	32.20
		(cm of water)	5.49	7.37	9.61
Feb 18/00	Snow Depth	(cm)	2.10	3.10	13.00
	Water Equivalency	(cm cm^{-1} of snow)	0.46	0.27	0.19
		(cm of water)	0.96	0.84	2.42
March 9/01	Snow Depth	(cm)	4.60	20.50	20.20
	Water Equivalency	(cm cm^{-1} of snow)	0.73	0.38	0.23
		(cm of water)	3.37	7.71	4.59

Note: Measurments are for last snow survey sample before runoff started in a given year, except in 1999 when there was a late snowfall after the initial spring runoff period that contributed additional runoff.

Data extracted from Yarotski and Miller (1999, 2000, 2001, 2002).

Appendix 7a. Mean, minimum, and maximum values for water quality data collected from the Natural Wooded Area, Forage Field, and the Manured Watershed sites during spring runoff, 1995 - 1998.

Station	Date		Suspended Solids	Phosphorus				Nitrogen					Carbon			Fecal Coliform
				Total	Dissolved	Particulate	Ortho-	Total	Dissolved	Particulate	Ammonia	Nitrate-nitrite	Total Organic	Dissolved Organic	Particulate Organic	
	(mm/dd/yy)		(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(No 100 mL^{-1})
Natural Wooded Area (Site # 10)		**Min**	25.9	0.072	0.048	0.024	0.045	0.970	0.536	0.275	0.006	0.157	10.43	5.77	3.19	
		Max	169.0	0.240	64.000	0.176	0.059	2.519	0.769	1.940	0.046	0.359	30.21	7.24	24.10	
	1995	**Mean**	**73.93**	**0.131**	**0.056**	**0.075**	**0.052**	**1.510**	**0.628**	**0.884**	**0.026**	**0.265**	**17.333**	**6.373**	**10.960**	
		Min	86.4	0.232	0.081	0.151	0.078	1.610	0.478	1.130	0.220	0.203	19.50	6.20	13.30	
		Max	86.4	0.232	0.081	0.151	0.078	1.610	0.478	1.130	0.220	0.203	19.50	6.20	13.30	
	1996	**Mean**	**86.40**	**0.232**	**0.081**	**0.151**	**0.078**	**1.610**	**0.478**	**1.130**	**0.220**	**0.203**	**19.500**	**6.200**	**13.300**	
		Min	4.2	0.094	0.080	0.033	0.043	0.700	0.484	0.047	0.012	0.180	7.71	5.71	0.49	
		Max	80.4	0.478	0.320	0.175	0.247	1.760	0.705	1.100	0.335	0.559	18.51	7.22	12.80	
	1997	**Mean**	**36.85**	**0.240**	**0.138**	**0.103**	**0.107**	**1.133**	**0.602**	**0.533**	**0.098**	**0.319**	**12.395**	**6.465**	**5.929**	
	1995-1997	**Mean**	**56.95**	**0.198**	**0.100**	**0.098**	**0.083**	**1.334**	**0.596**	**0.739**	**0.086**	**0.284**	**15.135**	**6.398**	**8.737**	
Forage Field (Site #9)	03/26/98															< 10
	03/28/98															< 10
	03/28/98															< 10
	03/30/98															10
		Min	1.6	0.079	0.068	0.011	0.060	0.391	0.366	0.025	0.022	0.027	6.62	6.29	0.33	< 10
	Spring Runoff	Max	1.6	0.079	0.068	0.011	0.060	0.391	0.366	0.025	0.022	0.027	6.62	6.29	0.33	10
		Mean	**1.60**	**0.079**	**0.068**	**0.011**	**0.060**	**0.391**	**0.366**	**0.025**	**0.022**	**0.027**	**6.617**	**6.290**	**0.327**	**10**
Upstream of Manured Watershed Weir (Site #8)	03/28/98															1140
	03/30/98															< 10
	03/31/98															290
	04/02/98															100
	04/06/98															< 10
																20
		Min	4.8	0.302	0.152	0.039	0.134	1.654	1.360	0.114	0.181	0.344	6.51	4.25	0.85	< 10
	Spring Runoff	Max	36.8	1.470	0.574	0.896	0.473	5.810	5.650	0.355	0.604	4.570	12.24	11.30	2.59	1140
		Mean	**16.67**	**0.780**	**0.418**	**0.362**	**0.569**	**3.060**	**2.850**	**0.210**	**0.361**	**1.874**	**8.528**	**7.070**	**1.458**	**64**
Manured Watershed Weir (Site #7)	03/26/98															< 10
	03/26/98															< 10
	03/28/98															< 10
	03/28/98															1570
	03/30/98															< 10
		Min	9.6	1.220	1.050	0.004	0.930	12.820	12.400	0.255	0.503	8.500	14.26	12.40	1.86	< 10
	Spring Runoff	Max	21.0	3.360	2.640	0.720	2.520	21.645	21.100	0.769	3.380	16.000	23.79	23.10	4.19	1570
		Mean	**13.80**	**2.256**	**2.030**	**0.224**	**1.823**	**18.352**	**17.778**	**0.512**	**2.317**	**13.269**	**18.442**	**17.856**	**3.125**	**27**
Downstream of Manured Watershed Weir (Site #5)	03/28/98															1990
	03/28/98															1920
	03/30/98															30
	03/31/98															40
	04/05/98															< 10
	04/06/98															< 10
		Min	6.0	0.439	0.368	0.040	0.323	1.361	1.250	0.111	0.157	0.414	7.20	6.18	0.75	< 10
	Spring Runoff	Max	7.6	1.270	1.230	0.071	1.110	6.984	6.790	0.194	0.263	5.210	16.71	15.60	1.11	1990
		Mean	**6.93**	**0.731**	**0.670**	**0.061**	**0.600**	**3.421**	**3.270**	**0.151**	**0.227**	**2.211**	**10.421**	**9.460**	**0.961**	**88**

Blanks = No data.

Note: Inquiries about availability of raw chemical data should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Fecal coliform mean values based upon geometric mean. Raw data for fecal coliform data provided.

Appendix 7b. Mean, minimum, and maximum values for water quality data collected from the Twin Waterhed sites during spring runoff, 1998.

Station	Date	Time	Suspended Solids	Phosphorus				Nitrogen					Carbon			Fecal Coliform
				Total	Dissolved	Particulate	Ortho-	Total	Dissolved	Particulate	Ammonia	Nitrate-nitrite	Total Organic	Dissolved Organic	Particulate Organic	
	(mm/dd/yy)	(h)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(No 100 mL⁻¹)
Upstream	03/26/98	1730														1130
site on	03/28/98															< 10
receiving	03/28/98															< 10
tributary	03/30/98															< 10
(Site #2)	03/31/98															< 10
	04/05/98	1303														< 10
	04/06/98	1300														< 10
		Min	2.4	0.202	0.187	0.015	0.176	1.781	1.740	0.041	0.021	1.350	5.16	4.88	0.28	< 10
		Max	12.4	0.433	0.394	0.039	0.349	2.410	2.220	0.190	0.133	1.660	10.16	9.40	1.35	1130
		Mean	**7.33**	**0.345**	**0.320**	**0.024**	**0.273**	**2.145**	**2.033**	**0.112**	**0.074**	**1.470**	**7.484**	**6.687**	**0.798**	**20**
Twin	03/26/98	1330														< 10
Watershed	03/26/98	1730														< 10
Conventional-	03/28/98	1341														< 10
till Field	03/30/98	1521														< 10
Weir	03/31/98															< 10
		Min	6.2	0.116	0.107	0.009	0.085	1.444	1.050	0.120	0.154	0.497	3.33	2.54	0.79	< 10
(Site #4)		**Max**	400.0	0.741	0.493	0.297	0.355	4.165	3.430	1.810	0.907	2.020	23.81	10.10	16.10	< 10
		Mean	**123.06**	**0.414**	**0.271**	**0.143**	**0.222**	**2.923**	**2.166**	**0.757**	**0.365**	**1.176**	**12.302**	**5.959**	**6.320**	**10**
Twin	03/26/98	1330														< 10
Watershed	03/26/98	1730														< 10
Zero-till	03/28/98	1337														< 10
Field Weir	03/28/98	1847														< 10
	03/30/98	1330														< 10
(Site #3)	03/31/98	1450														10
		Min	2.4	0.100	0.079	0.000	0.070	1.305	1.120	0.101	0.415	0.238	2.42	1.63	0.77	< 10
		Max	36.0	1.140	1.000	0.338	0.881	4.806	4.010	0.796	2.220	2.180	12.75	8.45	4.47	10
		Mean	**11.32**	**0.540**	**0.480**	**0.089**	**0.394**	**2.549**	**2.213**	**0.336**	**0.830**	**0.792**	**7.158**	**4.719**	**2.104**	**10**
Downstream	03/26/98	1400														210
site on	03/26/98	1730														130
receiving	03/28/98															40
tributaty	03/28/98															60
	03/30/98															120
(Site #1)	03/31/98															20
	04/05/98	1302														< 10
	04/06/98	1630														< 10
		Min	4.8	0.202	0.191	0.011	0.175	2.038	1.960	0.078	0.048	1.350	5.10	4.58	0.52	< 10
		Max	17.6	0.421	0.404	0.026	0.355	2.464	2.240	0.224	0.163	1.650	9.60	8.85	1.64	210
		Mean	**11.20**	**0.321**	**0.303**	**0.018**	**0.270**	**2.221**	**2.087**	**0.134**	**0.094**	**1.510**	**7.369**	**6.400**	**0.969**	**45**

Blanks = No data.

Note: Inquiries about availability of raw chemical data should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Fecal coliform mean values based upon geometric mean.

Raw data for fecal coliform data provided - Inquiries should be made to Manitoba Conservation Water Quality Management, 123 Main Street Winnipeg, R3C 1A5.

Appendix 8a. Mean, minimum, and maximum values for water quality data collected from the Natural Wooded Area, Manured Watershed, Conventional-till, and Zero-till field sites during spring runoff and summer 1999. (Water analyzes done at the Environment Canada Laboratory in Saskatoon,Saskatchewan.)

Station	Season		Suspended Solids	Phosphorus				Nitrogen					Organic Carbon		
				Total	Dissolved	Particulate	Orhto-	Total	Dissolved	Particulate	Ammonia	Nitrate-nitrite	Total	Dissolved	Particulate
			(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)
Natural Wooded Area (Site #10)	Spring runoff	Min	4.0	0.089	0.077	0.012	0.057	0.351	0.113	0.055	0.025	0.010	6.30	5.62	0.52
		Max	19.0	0.130	0.088	0.042	0.062	0.670	0.529	0.238	0.045	0.124	13.54	12.00	2.69
		Mean	**12.00**	**0.112**	**0.084**	**0.028**	**0.060**	**0.498**	**0.353**	**0.145**	**0.034**	**0.066**	**9.382**	**7.800**	**1.582**
	Summer	Min	22.8	0.158	0.122	0.036	0.106	0.695	0.384	0.311	0.016	0.085	10.74	7.11	3.63
		Max	22.8	0.158	0.122	0.036	0.106	0.695	0.384	0.311	0.016	0.085	10.74	7.11	3.63
		Mean	**22.80**	**0.158**	**0.122**	**0.036**	**0.106**	**0.695**	**0.384**	**0.311**	**0.016**	**0.085**	**10.740**	**7.110**	**3.630**
Manured Watershed Weir (Site #7)	Spring runoff	Min	9.2	0.467	0.415	0.052	2.030	3.280	2.770	0.488	0.142	1.090	10.89	8.04	2.66
		Max	160.0	2.660	2.220	0.440	2.030	7.260	4.100	3.160	1.350	2.270	48.70	15.50	33.20
		Mean	**50.30**	**1.271**	**1.041**	**0.230**	**2.030**	**4.543**	**3.273**	**1.269**	**0.869**	**1.488**	**23.113**	**12.260**	**10.853**
Twin Wateshed Conventional-till Field Weir (Site #4)	Spring Runoff	Min	30.0	0.390	0.114	0.082	0.081	6.901	0.483	0.353	0.153	0.056	11.02	2.48	2.53
		Max	1350.0	0.929	0.518	0.810	0.436	25.170	24.000	7.510	0.827	22.200	82.78	13.20	80.30
		Mean	**315.47**	**0.613**	**0.318**	**0.295**	**0.257**	**16.385**	**14.409**	**1.976**	**0.300**	**12.120**	**28.46**	**8.89**	**19.57**
	Summer	Min	129.0	0.374	0.132	0.130	0.110	1.463	0.422	0.721	0.042	0.174	11.70	2.43	6.68
		Max	354.0	0.496	0.331	0.273	0.293	2.918	0.742	2.190	0.171	0.299	23.31	5.02	20.50
		Mean	**241.50**	**0.432**	**0.213**	**0.219**	**0.184**	**2.016**	**0.593**	**1.423**	**0.080**	**0.220**	**17.32**	**3.30**	**14.02**
Twin Watershed Zero-till Field Weir (Site #3)	Spring Runoff	Min	5.6	0.397	0.298	0.051	0.262	2.148	1.860	0.198	0.142	0.939	7.93	6.18	1.13
		Max	990.0	2.900	1.730	1.170	1.630	26.550	20.800	5.750	5.460	14.800	63.87	18.00	55.60
		Mean	**113.08**	**0.809**	**0.610**	**0.199**	**0.546**	**6.154**	**5.268**	**0.886**	**0.677**	**3.559**	**16.86**	**9.50**	**7.37**
	Summer	Min	44.0	0.777	0.392	0.100	0.368	1.459	0.757	0.449	0.077	0.260	8.37	3.31	3.25
		Max	769.0	1.240	1.140	0.696	1.060	4.580	2.360	3.000	0.327	1.340	30.80	6.84	27.20
		Mean	**322.25**	**0.960**	**0.645**	**0.315**	**0.584**	**2.885**	**1.404**	**1.481**	**0.197**	**0.707**	**17.59**	**4.63**	**12.96**

Note: Enquiries about availability of raw data should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Appendix 8b. Water quality data collected from the Natural Wooded Area, Forage Field, and the Manured Watershed sites during spring runoff 1999. (Water analyses done at at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
				Total	Dissolved	Particulate	Ortho-	Total	Dissolved	Particulate	Total Kjeldahl	Dissolved Kjeldahl	Ammonia	Nitrate-nitrite Soluble	Nitrate-nitrite dissolved	Total	Dissolved	Particulate	
	(mm/dd/yy)	(Units)	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(No 100 mL^{-1})
Natural Wooded Area (Site #10)	04-07-99	7.86	11.0	0.088	0.082	0.006	0.079	0.82	0.62	0.200	0.7	0.5	0.040	0.120	0.120	5	6	0	10
	04-12-99																		<10
	Mean	**7.86**	**11.00**	**0.088**	**0.082**	**0.006**	**0.079**	**0.820**	**0.620**	**0.200**	**0.700**	**0.500**	**0.040**	**0.120**	**0.120**	**5.000**	**6.000**	**0.000**	**10**
Forage Field) (Site #9)	03-15-99	7.31	5.0	1.530	1.430	0.100	1.420	4.03	3.22	0.810	3.2	2.4	1.210	0.830	0.820	16	15	1	210
	03-16-99	7.62	5.0	2.700	2.510	0.190	2.470	7.30	5.83	1.470	5.4	3.9	1.290	1.900	1.930	36	33	3	610
	03-20-99	7.27	12.0	1.680	1.470	0.210	1.470	5.32	4.50	0.820	4.7	3.9	1.220	0.620	0.600	28	26	2	420
	03-21-99	7.46	5.0	1.340	1.210	0.130	1.260	2.76	2.05	0.710	2.4	1.7	0.370	0.360	0.350	18	16	2	320
	03-22-99	7.63	5.0	1.210	1.050	0.160	1.130	2.61	1.81	0.800	2.4	1.6	0.380	0.210	0.210	16	13	3	260
	03-26-99	7.74	5.0	1.110	0.959	0.151	1.160	2.24	1.34	0.900	2.1	1.2	0.140	0.140	0.140	15	15	0	190
	04-07-99	7.83	5.0	0.329	0.310	0.019	0.296	1.47	1.47	0.000	1.4	1.4	0.060	0.070	0.070	19	18	1	70
	05-22-99	7.81	5.0	0.194	0.200	0.000		0.51	0.61	0.000	0.5	0.6	0.010	0.010	0.010	11	12	0	0
	Mean	**7.58**	**5.88**	**1.262**	**1.142**	**0.120**	**1.315**	**3.280**	**2.604**	**0.689**	**2.763**	**2.088**	**0.585**	**0.518**	**0.516**	**19.875**	**18.500**	**1.500**	**125**
Upstream of Manured Watershed Weir (Site #8)	03-20-99	7.46	13.0	1.470	1.370	0.100	1.390	5.50	4.96	0.540	1.9	1.4	0.030	3.600	3.560	19	17	2	<10
	03-21-99	7.69	5.0	1.700	1.580	0.120	1.630	6.39	5.45	0.940	2.2	1.7	0.070	4.190	3.750	22	19	3	<10
	03-22-99	7.80	5.0	1.630	1.520	0.110	1.650	5.77	5.71	0.060	2.0	1.8	0.020	3.770	3.910	20	19	1	<10
	03-26-99	7.52	12.0	0.603	0.578	0.025	0.592	0.88	0.78	0.100	0.7	0.6	0.040	0.180	0.180	9	9	0	30
	04-07-99	7.31	14.0	0.163	0.123	0.040	0.132	0.79	0.78	0.010	0.7	0.7	0.040	0.090	0.080	9	8	1	<10
	04-08-99	7.76	24.0	1.280	1.190	0.090	1.300	5.76	5.89	-0.130	1.6	1.6	0.040	4.160	4.290	18	18	0	<10
	05-20-99	7.61	490.0	1.960	0.822	1.138	0.912	8.23	2.85	5.380	6.9	1.5	0.540	1.330	1.350	14	13	1	40
	05-22-99	7.59	420.0	1.380	0.990	0.390		6.56	5.05	1.510	2.8	1.2	0.480	3.760	3.850	11	8	3	93
	05-22-99	7.67	310.0	1.140	0.807	0.333		2.89	1.60	1.290	2.3	1.0	0.070	0.590	0.600	13	10	3	230
	Mean	**7.60**	**143.67**	**1.258**	**0.998**	**0.261**	**1.087**	**4.752**	**3.674**	**1.078**	**2.344**	**1.278**	**0.142**	**2.408**	**2.397**	**15.000**	**13.444**	**1.556**	**24**
Ditch site upstream of Manured Watershed Weir (Site #6)	04-07-99	7.14	5.0	0.461	0.426	0.035	0.428	4.48	4.49	-0.010	0.8	0.7	0.030	3.680	3.790	10	9	1	270
	04-08-99	7.36	5.0	0.857	0.814	0.043	0.866	3.44	3.19	0.250	1.5	1.2	0.110	1.940	1.990	15	14	1	50
	05-20-99	7.45	5.0	0.532	0.501	0.031	0.526	1.33	1.12	0.210	1.3	1.1	0.040	0.030	0.020	16	16	0	<10
	05-22-99	7.31	690.0	0.930	0.475	0.455		3.21	1.46	1.750	2.6	0.8	0.120	0.610	0.660	14	9	5	93
	05-22-99	7.36	350.0	0.938	0.517	0.421		5.35	3.88	1.470	2.3	0.8	0.400	3.050	3.080	10	8	2	93
	Mean	**7.32**	**211.00**	**0.744**	**0.547**	**0.197**	**0.607**	**3.562**	**2.828**	**0.734**	**1.700**	**0.920**	**0.140**	**1.862**	**1.908**	**13.000**	**11.200**	**1.800**	**41**
Manaured Waterhsed Weir (Site #7)	03-15-99	7.21	8.0	0.492	0.393	0.099	0.374	4.43	3.44	0.990	3.1	2.1	1.020	1.330	1.340	10	10	0	30
	03-15-99																		40
	03-16-99																		<10
	05-22-99																		7
	Mean	**7.21**	**8.00**	**0.492**	**0.393**	**0.099**	**0.374**	**4.430**	**3.440**	**0.990**	**3.100**	**2.100**	**1.020**	**1.330**	**1.340**	**10.000**	**10.000**	**0.000**	**17**
Downstteam of Manured Watershed Weir (Site #5)	05-20-99	7.72	480.0	1.550	0.828	0.722	0.872	4.30	1.50	2.800	4.2	1.4	0.070	0.100	0.100	20	17	3	1200
	05-22-99	7.33	570.0	0.945	0.468	0.477		3.17	1.17	2.000	2.6	0.6	0.080	0.570	0.570	15	8	7	430
	05-22-99	7.84	250.0	0.820	0.679	0.141		1.54	0.94	0.600	1.4	0.8	0.040	0.140	0.140	14	12	2	240
	Mean	**7.63**	**433.33**	**1.105**	**0.658**	**0.447**	**0.872**	**3.003**	**1.203**	**1.800**	**2.733**	**0.933**	**0.063**	**0.270**	**0.270**	**16.333**	**12.333**	**4.000**	**488**

Blanks = No data.

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note: Negavtive values for particulate calculation sometimes occurred where total concentrations were less than dissolved values These differences were very small and result from analytical variatons

Shading = calculated value was a negative number so assumed zero

Fecal coliform mean values based upon geometric mean

Appendix 8c. Water quality data collected from the Conventional-till and Zero-till field sites during spring runoff 1999. (Water analyses done at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
	(mm/dd/yy)	(Units)	(mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	Ortho- (mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	Total Kjeldahl (mg L⁻¹)	Dissolved Kjeldahl (mg L⁻¹)	Ammonia (mg L⁻¹)	Nitrate-nitrite Soluble (mg L⁻¹)	Nitrate-nitrite dissolved (mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	(No. 100 mL⁻¹)
Upstream	03-20-99	7.36	29.0	1.570	1.400	0.170	1.400	8.63	7.91	0.720	3.2	2.4	0.600	5.430	5.410	19	18	1	260
site on	03-21-99	7.08	17.0	0.762	0.652	0.110	0.719	9.23	8.79	0.440	1.9	1.5	0.540	7.330	7.290	13	12	1	230
receiving	03-22-99	7.52	7.0	1.390	1.280	0.110	1.380	13.00	12.30	0.700	2.4	2.0	0.220	10.600	10.300	19	18	1	120
tributary	03-22-99	7.56	5.0	1.190	1.110	0.080	1.200	13.20	13.10	0.100	2.2	2.2	0.170	11.000	10.900	18	16	2	140
	03-23-99	7.50	5.0	0.951	0.866	0.085	0.968	12.20	12.30	**0.000**	0.7	1.0	0.070	11.500	11.300	14	15	**0**	90
(Site #2)	03-25-99	7.60	5.0	0.480	0.443	0.037	0.474	8.51	8.06	0.450	0.8	0.2	0.040	7.710	7.860	13	13	0	80
	03-26-99	7.56	10.0	0.573	0.539	0.034	0.564	6.87	6.50	0.370	0.9	0.5	0.070	5.970	6.000	13	12	0	20
	04-07-99	7.63	98.0	0.542	0.379	0.163	0.415	18.50	17.90	0.600	1.5	0.2	0.110	17.000	17.700	9	10	**0**	40
	05-22-99	7.71	71.0	0.250	0.180	0.070		1.60	1.49	0.110	0.8	0.7	0.020	0.800	0.790	8	7	1	210
	Mean	**7.502**	**27.44**	**0.856**	**0.761**	**0.095**	**0.890**	**10.193**	**9.817**	**0.388**	**1.600**	**1.189**	**0.204**	**8.593**	**8.628**	**13.889**	**13.444**	**0.667**	**101**
Twin	03-19-99																		<10
Watershed	03-20-99	7.16	120.0	0.481	0.377	0.104	0.437	17.60	16.80	0.800	2.6	1.4	0.270	15.000	15.400	15	13	2	<10
Conventional-	03-20-99																		20
till Field	03-21-99																		<10
Weir	03-22-99																		<10
	03-22-99																		<10
(Site #4)	03-23-99																		<10
	03-25-99	7.13	72.0	0.560	0.345	0.215	0.431	17.00	16.70	0.300	2.1	0.9	0.230	14.900	15.800	16	13	3	<10
	03-26-99	7.18	190.0	0.609	0.335	0.274	0.399	18.80	13.10	5.700	6.5	0.7	0.220	12.300	12.400	15	11	1	<10
	04-07-99	6.73	290.0	0.546	0.203	0.343	0.204	22.70	21.60	1.100	2.4	0.2	0.170	20.300	21.400	10	9	1	<10
	Mean	**7.050**	**168.00**	**0.549**	**0.315**	**0.234**	**0.368**	**19.025**	**17.050**	**1.975**	**3.400**	**0.800**	**0.223**	**15.625**	**16.250**	**14.000**	**12.250**	**1.750**	**11**
Twin	03-16-99	6.99	7.0	0.870	0.736	0.134	0.740	5.88	5.13	0.750	3.0	2.3	0.540	2.880	2.830	20	19	1	20
Watershed	03-16-99																		60
Zero-till	03-19-99																		60
Field Weir	03-20-99	7.09	6.0	0.620	0.555	0.065	0.584	2.93	3.04	**0.000**	1.6	1.7	0.270	1.330	1.340	12	11	1	<10
	03-20-99																		10
(Site #3)	03-21-99																		140
	03-22-99																		<10
	03-22-99																		20
	03-23-99																		<10
	03-25-99	6.93	14.0	0.555	0.414	0.141	0.560	5.04	4.25	0.790	1.9	1.1	0.250	3.140	3.150	12	11	1	<10
	03-26-99	6.91	28.0	0.534	0.371	0.163	0.500	3.89	3.31	0.580	1.9	1.3	0.270	1.990	2.010	9	9	0	<10
	04-07-99	6.98	56.0	0.779	0.570		0.553	6.55	6.29	0.260	1.9	1.5	0.100	4.650	4.790	15	14	1	10
	Mean	**6.980**	**22.20**	**0.672**	**0.529**	**0.126**	**0.587**	**4.858**	**4.404**	**0.476**	**2.060**	**1.580**	**0.286**	**2.798**	**2.824**	**13.600**	**12.800**	**0.800**	**19**
Downstream	03-16-99	7.23	17.0	1.260	1.160	0.100	1.130	6.78	5.83	0.950	3.5	2.5	0.600	3.280	3.330	22	21	1	1140
site on	03-19-99	7.21	12.0	0.775	0.708	0.067	0.712	4.63	4.13	0.500	2.7	2.2	0.410	1.930	1.930	14	13	1	590
receiving	03-20-99	7.16	6.0	0.628	0.568	0.060	0.607	4.40	4.52	-0.120	1.9	2.0	0.250	2.500	2.420	13	11	2	710
tributary	03-20-99	6.98	13.0	0.702	0.601	0.101	0.645	5.17	5.12	0.050	1.8	1.8	0.310	3.370	3.320	14	13	1	540
	03-21-99	7.18	7.0	0.711	0.653	0.058	0.686	3.90	3.70	0.200	1.6	1.4	0.210	2.300	2.300	13	12	1	450
(Site #1)	03-21-99	7.05	15.0	0.683	0.565	0.118	0.627	7.32	6.63	0.690	1.9	1.6	0.230	5.420	5.030	14	11	3	650
	03-22-99	7.07	66.0	0.728	0.499	0.229	0.623	12.02	11.60	0.420	2.2	1.6	0.260	9.820	10.000	14	12	2	1390
	03-22-99	7.11	12.0	0.719	0.585	0.134	0.688	5.17	4.88	0.290	1.5	1.1	0.220	3.670	3.780	13	11	2	370
	03-23-99	7.45	5.0	0.931	0.842	0.089	0.940	12.00	11.10	0.900	1.4	0.4	0.080	10.600	10.700	15	13	2	60
	03-25-99	7.35	19.0	0.601	0.509	0.092	0.547	6.84	6.68	0.160	1.0	0.8	0.150	5.840	5.880	14	13	1	450
	03-26-99	7.35	40.0	0.597	0.495	0.102	0.516	5.69	5.02	0.670	1.5	0.8	0.130	4.190	4.220	11	11	0	270
	04-07-99	7.54	98.0	0.583	0.430	0.153	0.443	16.60	14.40	2.200	1.5	0.2	0.100	15.100	14.200	10	10	0	80
	05-22-99	7.67	70.0	0.271	0.188	0.083		1.98	1.68	0.300	0.9	0.6	0.060	1.080	1.080	8	7	1	430
	Mean	**7.258**	**29.23**	**0.707**	**0.600**	**0.107**	**0.680**	**7.115**	**6.561**	**0.555**	**1.800**	**1.308**	**0.232**	**5.315**	**5.253**	**13.462**	**12.154**	**1.308**	**411**

Blanks = No data

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note: Negative values for particulate calculation sometimes occurred where total concentrations were less than dissolved values. These differences were very small and result from analytical variatons

Shading = calculated value a negative number so assumed zero

Fecal coliform mean values based upon geometric means.

Appendix 8b. Water quality data collected from the Natural Wooded Area, Forage Field, and the Manured Watershed sites during spring runoff 1999. (Water analyses done at at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
	(mm/dd/yy)	(Units)	(mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	Ortho (mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	Total Kjeldahl (mg L⁻¹)	Dissolved Kjeldahl (mg L⁻¹)	Ammonia (mg L⁻¹)	Nitrate-nitrite Soluble (mg L⁻¹)	Nitrate-nitrite dissolved (mg L⁻¹)	Total (mg L⁻¹)	Dissolved (mg L⁻¹)	Particulate (mg L⁻¹)	(No. 100 mL⁻¹)
Natural Wooded Area (Site #10)	04-07-99	7.86	11.0	0.088	0.082	0.006	0.079	0.82	0.62	0.200	0.7	0.5	0.040	0.120	0.120	5	6	0	10
	04-12-99																		<10
	Mean	**7.86**	**11.00**	**0.088**	**0.082**	**0.006**	**0.079**	**0.820**	**0.620**	**0.200**	**0.700**	**0.500**	**0.040**	**0.120**	**0.120**	**5.000**	**6.000**	**0.000**	**10**
Forage Field (Site #9)	03-15-99	7.31	5.0	1.530	1.430	0.100	1.420	4.03	3.22	0.810	3.2	2.4	1.210	0.830	0.820	16	15	1	210
	03-16-99	7.62	5.0	2.700	2.510	0.190	2.470	7.36	5.83	1.470	5.4	3.9	1.290	1.900	1.930	36	33	3	610
	03-20-99	7.27	12.0	1.680	1.470	0.210	1.470	5.32	4.50	0.820	4.7	3.9	1.220	0.620	0.600	28	26	2	420
	03-21-99	7.46	5.0	1.340	1.210	0.130	1.260	2.76	2.05	0.710	2.4	1.7	0.370	0.360	0.350	18	16	2	320
	03-22-99	7.63	5.0	1.210	1.050	0.160	1.130	2.61	1.81	0.800	2.4	1.6	0.380	0.210	0.210	16	13	3	260
	03-26-99	7.74	5.0	1.110	0.959	0.151	1.160	2.24	1.34	0.900	2.1	1.2	0.140	0.140	0.140	15	15	0	190
	04-07-99	7.83	5.0	0.329	0.310	0.019	0.296	1.47	1.47	0.000	1.4	1.4	0.060	0.070	0.070	19	18	1	70
	05-22-99	7.81	5.0	0.194	0.200	0.000		0.51	0.61	0.000	0.5	0.6	0.010	0.010	0.010	11	12	0	0
	Mean	**7.58**	**5.88**	**1.262**	**1.142**	**0.120**	**1.315**	**3.280**	**2.604**	**0.689**	**2.763**	**2.088**	**0.585**	**0.518**	**0.516**	**19.875**	**18.500**	**1.500**	**125**
Upstream of Manured Watershed Weir (Site #8)	03-20-99	7.46	13.0	1.470	1.370	0.100	1.390	5.50	4.96	0.540	1.9	1.4	0.030	3.600	3.560	19	17	2	<10
	03-21-99	7.69	5.0	1.700	1.580	0.120	1.630	6.39	5.45	0.940	2.2	1.7	0.020	4.190	3.750	22	19	3	<10
	03-22-99	7.80	5.0	1.630	1.520	0.110	1.650	5.77	5.71	0.060	2.0	1.8	0.020	3.770	3.910	20	19	1	<10
	03-26-99	7.52	12.0	0.603	0.578	0.025	0.592	0.88	0.78	0.100	0.7	0.6	0.040	0.180	0.180	9	9	0	30
	04-07-99	7.31	14.0	0.163	0.123	0.040	0.132	0.79	0.78	0.010	0.7	0.7	0.040	0.090	0.080	9	8	1	<10
	04-08-99	7.76	24.0	1.280	1.190	0.090	1.300	5.76	5.89	0.130	1.6	1.6	0.040	4.160	4.290	18	18	0	<10
	05-20-99	7.61	490.0	1.960	0.822	1.138	0.912	8.23	2.85	5.380	6.9	1.5	0.540	1.330	1.350	14	13	1	40
	05-22-99	7.59	420.0	1.380	0.990	0.390		6.56	5.05	1.510	2.8	1.2	0.480	3.760	3.850	11	8	3	93
	05-22-99	7.67	310.0	1.140	0.807	0.333		2.89	1.60	1.290	2.3	1.0	0.070	0.590	0.600	13	10	3	230
	Mean	**7.60**	**143.67**	**1.258**	**0.998**	**0.261**	**1.087**	**4.752**	**3.674**	**1.078**	**2.344**	**1.278**	**0.142**	**2.408**	**2.397**	**15.000**	**13.444**	**1.556**	**24**
Ditch site upstream of Manured Watershed Weir (Site #6)	04-07-99	7.14	5.0	0.461	0.426	0.035	0.428	4.48	4.49	0.010	0.8	0.7	0.030	3.680	3.790	10	9	1	270
	04-08-99	7.36	5.0	0.857	0.814	0.043	0.866	3.44	3.19	0.250	1.5	1.2	0.110	1.940	1.990	15	14	1	50
	05-20-99	7.45	5.0	0.532	0.501	0.031	0.526	1.33	1.12	0.210	1.3	1.1	0.040	0.030	0.020	16	16	0	<10
	05-22-99	7.31	690.0	0.930	0.475	0.455		3.21	1.46	1.750	2.6	0.8	0.120	0.610	0.660	14	9	5	93
	05-22-99	7.36	350.0	0.938	0.517	0.421		5.35	3.88	1.470	2.3	0.8	0.400	3.050	3.080	10	8	2	93
	Mean	**7.32**	**211.00**	**0.744**	**0.547**	**0.197**	**0.607**	**3.562**	**2.828**	**0.734**	**1.700**	**0.920**	**0.140**	**1.862**	**1.908**	**13.000**	**11.200**	**1.800**	**41**
Manaured Waterhsed Weir (Site #7)	03-15-99	7.21	8.0	0.492	0.393	0.099	0.374	4.43	3.44	0.990	3.1	2.1	1.020	1.330	1.340	10	10	0	30
	03-15-99																		40
	03-16-99																		<10
	05-22-99																		7
	Mean	**7.21**	**8.00**	**0.492**	**0.393**	**0.099**	**0.374**	**4.430**	**3.440**	**0.990**	**3.100**	**2.100**	**1.020**	**1.330**	**1.340**	**10.000**	**10.000**	**0.000**	**17**
Downstteam of Manured Watershed Weir (Site #5)	05-20-99	7.72	480.0	1.550	0.828	0.722	0.872	4.30	1.50	2.800	4.2	1.4	0.070	0.100	0.100	20	17	3	1200
	05-22-99	7.33	570.0	0.945	0.468	0.477		3.17	1.17	2.000	2.6	0.6	0.080	0.570	0.570	15	8	7	430
	05-22-99	7.84	250.0	0.820	0.679	0.141		1.54	0.94	0.600	1.4	0.8	0.040	0.140	0.140	14	12	2	230
	Mean	**7.63**	**433.33**	**1.105**	**0.658**	**0.447**	**0.872**	**3.003**	**1.203**	**1.800**	**2.733**	**0.933**	**0.063**	**0.270**	**0.270**	**16.333**	**12.333**	**4.000**	**488**

Blanks = No data

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note Negavtive values for particulate calculation sometimes occurred where total concentrations were less than dissolved values These differences were very small and result from analytical variatons

Shading = calculated value was a negative number so assumed zero

Fecal coliform mean values based upon geometric mean

Appendix 8c. Water quality data collected from the Conventional-till and Zero-till field sites during spring runoff 1999. (Water analyses done at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
				Total	Dissolved	Particulate	Ortho-	Total	Dissolved	Particulate	Total Kjeldahl	Dissolved Kjeldahl	Ammonia	Nitrate-nitrite Soluble	Nitrate-nitrite dissolved	Total	Dissolved	Particulate	
	(mm/dd/yy)	(Units)	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(No. 100 ml^{-1})
Upstream site on receiving tributary (Site #2)	03-20-99	7.36	29.0	1.570	1.400	0.170	1.400	8.63	7.91	0.720	3.2	2.4	0.600	5.430	5.510	19	18	1	260
	03-21-99	7.08	17.0	0.762	0.652	0.110	0.719	9.23	8.79	0.440	1.9	1.5	0.540	7.330	7.290	13	12	1	230
	03-22-99	7.52	7.0	1.390	1.280	0.110	1.380	13.00	12.30	0.700	2.4	2.0	0.220	10.600	10.300	19	18	1	120
	03-22-99	7.56	5.0	1.190	1.110	0.080	1.200	13.20	13.10	0.100	2.2	2.2	0.170	11.000	10.900	18	16	2	140
	03-23-99	7.50	5.0	0.951	0.866	0.085	0.968	12.20	12.30	**0.000**	0.7	1.0	0.070	11.500	11.300	14	15	**0**	90
	03-25-99	7.60	5.0	0.480	0.443	0.037	0.474	8.51	8.06	0.450	0.8	0.2	0.040	7.710	7.860	13	13	0	80
	03-26-99	7.56	10.0	0.573	0.539	0.034	0.564	6.87	6.50	0.370	0.9	0.5	0.070	5.970	6.000	12	12	0	20
	04-07-99	7.63	98.0	0.542	0.379	0.163	0.415	18.50	17.90	0.600	1.5	0.2	0.110	17.000	17.700	9	10	**0**	40
	05-22-99	7.71	71.0	0.250	0.180	0.070		1.60	1.49	0.110	0.8	0.7	0.020	0.800	0.790	8	7	1	210
	Mean	**7.502**	**27.44**	**0.856**	**0.761**	**0.095**	**0.890**	**10.193**	**9.817**	**0.388**	**1.600**	**1.189**	**0.204**	**8.593**	**8.628**	**13.889**	**13.444**	**0.667**	**101**
Twin Watershed Conventional-till Field Weir (Site #4)	03-19-99																		<10
	03-20-99	7.16	120.0	0.481	0.377	0.104	0.437	17.60	16.80	0.800	2.6	1.4	0.270	15.000	15.400	15	13	2	<10
	03-20-99																		20
	03-21-99																		<10
	03-22-99																		<10
	03-22-99																		<10
	03-23-99																		<10
	03-25-99	7.13	72.0	0.560	0.345	0.215	0.431	17.00	16.70	0.300	2.1	0.9	0.230	14.900	15.800	16	13	3	<10
	03-26-99	7.18	190.0	0.609	0.335	0.274	0.399	18.80	13.10	5.700	6.5	0.7	0.220	12.300	12.400	15	14	1	<10
	04-07-99	6.73	290.0	0.546	0.203	0.343	0.204	22.70	21.60	1.100	2.4	0.2	0.170	20.300	21.400	10	9	1	<10
	Mean	**7.050**	**168.00**	**0.549**	**0.315**	**0.234**	**0.368**	**19.025**	**17.050**	**1.975**	**3.400**	**0.800**	**0.223**	**15.625**	**16.250**	**14.000**	**12.250**	**1.750**	**11**
Twin Watershed	03-16-99	6.99	7.0	0.870	0.736	0.134	0.740	5.88	5.13	0.750	3.0	2.3	0.540	2.880	2.830	20	19	1	20
	03-16-99																		60
Zero-till Field Weir (Site #3)	03-19-99																		60
	03-20-99	7.09	6.0	0.620	0.555	0.065	0.584	2.93	3.04	**0.000**	1.6	1.7	0.270	1.330	1.340	12	11	1	<10
	03-20-99																		10
	03-21-99																		140
	03-22-99																		<10
	03-22-99																		20
	03-23-99																		<10
	03-25-99	6.93	14.0	0.555	0.414	0.141	0.560	5.04	4.25	0.790	1.9	1.1	0.250	3.140	3.150	12	11	1	<10
	03-26-99	6.91	28.0	0.534	0.371	0.163	0.500	3.89	3.31	0.580	1.9	1.3	0.270	1.990	2.010	9	9	0	<10
	04-07-99	6.98	56.0	0.779	0.570		0.553	6.55	6.29	0.260	1.9	1.5	0.100	4.650	4.700	15	14	1	10
	Mean	**6.980**	**22.20**	**0.672**	**0.529**	**0.126**	**0.587**	**4.858**	**4.404**	**0.476**	**2.060**	**1.580**	**0.286**	**2.798**	**2.824**	**13.600**	**12.800**	**0.800**	**19**
Downstream site on receiving tributary (Site #1)	03-16-99	7.23	17.0	1.260	1.160	0.100	1.130	6.78	5.83	0.950	3.5	2.5	0.600	3.280	3.330	22	21	1	1140
	03-19-99	7.21	12.0	0.775	0.708	0.067	0.712	4.63	4.13	0.500	2.7	2.2	0.410	1.930	1.930	14	13	1	560
	03-20-99	7.16	6.0	0.628	0.568	0.060	0.607	4.40	4.52	-0.120	1.9	2.0	0.250	2.500	2.520	13	11	2	710
	03-20-99	6.98	13.0	0.702	0.601	0.101	0.645	5.17	5.12	0.050	1.8	1.8	0.310	3.370	3.320	14	13	1	540
	03-21-99	7.18	7.0	0.711	0.653	0.058	0.686	3.90	3.70	0.200	1.6	1.4	0.210	2.300	2.300	13	12	1	450
	03-21-99	7.05	15.0	0.683	0.565	0.118	0.627	7.32	6.63	0.690	1.9	1.6	0.230	5.420	5.030	14	11	3	650
	03-22-99	7.07	66.0	0.728	0.499	0.229	0.623	12.02	11.60	0.420	2.2	1.6	0.260	9.820	10.000	14	12	2	1390
	03-22-99	7.11	12.0	0.719	0.585	0.134	0.688	5.17	4.88	0.290	1.5	1.1	0.220	3.670	3.780	13	11	2	370
	03-23-99	7.45	5.0	0.931	0.842	0.089	0.940	12.00	11.10	0.900	1.4	0.4	0.080	10.600	10.700	15	13	2	60
	03-25-99	7.35	19.0	0.601	0.509	0.092	0.547	6.84	6.68	0.160	1.0	0.8	0.150	5.840	5.880	14	13	1	450
	03-26-99	7.35	40.0	0.597	0.495	0.102	0.516	5.69	5.02	0.670	1.5	0.8	0.130	4.190	4.220	11	11	0	270
	04-07-99	7.54	98.0	0.583	0.430	0.153	0.443	16.60	14.40	2.200	1.5	0.2	0.100	15.100	14.200	10	10	0	80
	05-22-99	7.67	70.0	0.271	0.188	0.083		1.98	1.68	0.300	0.9	0.6	0.060	1.080	1.080	8	7	1	430
	Mean	**7.258**	**29.23**	**0.707**	**0.600**	**0.107**	**0.680**	**7.115**	**6.561**	**0.555**	**1.800**	**1.308**	**0.232**	**5.315**	**5.253**	**13.462**	**12.154**	**1.308**	**411**

Blanks = No data

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note Negative values for particulate calculation sometimes occurred where total concentrations were less than dissolved values These differences were very small and result from analytical variatons

Shading = calculated value a negative number so assumed zero

Fecal coliform mean values based upon geometric means.

Appendix 9a. Mean, minimum, and maxium values for water quality data collected from the Natural Wooded Area, Conventional-till and Zero-till field sites during spring runoff and summer 2000. (Water analyses done at the Environment Canada Laboratory in Saskatoon, Saskatchewan.)

Station	Season	Time	Suspended Solids	Phosphorus				Nitrogen					Organic Carbon		
				Total	Dissolved	Particulate	Orhto-	Total	Dissolved	Particulate	Ammonia	Nitrate-nitrite	Total	Dissolved	Particulate
		(h)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)
Natural Wooded Area (Site #10)	Sprin runoff	**Min**	20.0	0.149	0.090 #	0.059	0.082	0.634	0.404	0.230	0.030	0.135	8.39	5.39	3.00
		Max	20.0	0.149	0.090 #	0.059	0.082	0.634	0.404	0.230	0.030	0.135	8.39	5.39	3.00
		Mean	**20.00**	**0.149**	**0.090**	**0.059**	**0.082**	**0.634**	**0.404**	**0.230**	**0.030**	**0.135**	**8.390**	**5.390**	**3.000**
	Summer	**Min**	1.8	0.171	0.171	0.000	0.150	0.434	0.415	0.019	0.030	0.066	7.43	7.23	0.20
		Max	1.8	0.171	0.171	0.000	0.150	0.434	0.415	0.019	0.030	0.066	7.43	7.23	0.20
		Mean	**1.80**	**0.171**	**0.171**	**0.000**	**0.150**	**0.434**	**0.415**	**0.019**	**0.030**	**0.066**	**7.428**	**7.230**	**0.198**
	November	**Min**	1.0	0.183	0.181	0.002	0.162	0.409	0.399	0.041	0.019	0.044	8.53	8.36	0.17
		Max	3.2	0.277	0.262	0.015	0.238	0.709	0.668	0.041	0.019	0.044	14.57	14.20	0.37
		Mean	**2.10**	**0.230**	**0.222**	**0.009**	**0.200**	**0.559**	**0.534**	**0.041**	**0.019**	**0.044**	**11.550**	**11.280**	**0.270**
Twin Wateshed Conventional-till Field Weir (Site #4)	Summer	**Min**	98.4	0.652	0.538	0.036	0.493	5.210	3.010	1.350	0.195	1.870	19.39	8.13	8.37
		Max	1130.0	1.600	1.200	0.992	1.110	10.730	4.100	7.720	0.405	2.720	77.43	13.80	69.30
		Mean	**447.80**	**1.261**	**0.785**	**0.476**	**0.743**	**7.227**	**3.657**	**3.570**	**0.307**	**2.357**	**39.663**	**10.073**	**29.590**
	November	**Min**	130.0	1.600	1.400	0.200	1.280	11.270	9.900	1.370	0.897	6.340	29.48	19.30	8.48
		Max	229.0	2.180	1.910	0.290	1.670	17.920	15.800	2.120	1.570	11.800	33.40	23.60	14.10
		Mean	**163.67**	**1.880**	**1.627**	**0.253**	**1.470**	**15.510**	**13.833**	**1.677**	**1.326**	**9.747**	**31.760**	**21.300**	**10.460**
Twin Watershed Zero-till Field Weir (Site #3)	Spring runoff	**Min**	4.8	1.160	1.060	0.070	0.120	3.821	3.350	0.247	0.086	2.030	14.29	11.50	1.34
		Max	35.2	1.930	1.840	0.130	1.690	10.422	9.843	0.632	0.328	7.700	25.24	22.10	4.36
		Mean	**17.28**	**1.552**	**1.448**	**0.104**	**1.234**	**6.308**	**5.861**	**0.446**	**0.174**	**4.243**	**17.215**	**14.530**	**2.685**
	Summer	**Min**	56.4	1.060	0.738	0.190	0.662	4.910	2.600	0.971	0.211	1.230	21.34	10.60	5.64
		Max	321.0	1.860	1.600	0.497	1.540	6.191	5.220	2.820	0.393	3.120	30.90	16.90	20.30
		Mean	**145.17**	**1.548**	**1.252**	**0.297**	**1.201**	**5.499**	**3.828**	**1.670**	**0.289**	**2.282**	**24.707**	**13.433**	**11.273**
	November	**Min**	12.4	1.320	1.140	0.090	1.030	2.976	2.200	0.625	0.199	0.557	16.38	11.60	3.43
		Max	41.2	2.080	1.990	0.180	1.840	3.570	2.840	1.120	0.432	0.794	19.53	16.10	7.15
		Mean	**23.92**	**1.686**	**1.552**	**0.134**	**1.424**	**3.313**	**2.482**	**0.831**	**0.303**	**0.694**	**18.058**	**13.040**	**5.018**

Blanks = No data.

Note: Inquiries about availability of raw data should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Appendix 9b. Water quality data collected from the Natural Wooded Area, Forage-Field, and the Conventional-till and Zero-till field sites during spring runoff 2000. (Water analyses done at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
				Total	Dissolved	Particulate	Ortho-	Total	Dissolved	Particulate	Total Kjeldahl	Dissolved Kjeldahl	Ammonia	Nitrate-nitrite Soluble	Nitrate-nitrite dissolved	Total	Dissolved	Particulate	
	(mm/dd/yy)	(Units)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(No 100mL⁻¹)
Natural Wooded Area (Site #10)	02-26-00																		< 10
	Mean																		**< 10**
Forage Field (Site #9)	02-26-00	7 18	< 5	1 340	1 230		1 150				2 100	# 1 500	0 160	0 240	0 170	18	18	0	440
	Mean	**7.18**	**< 5**	**1.340**	**1.230**		**1.150**				**2.100**	**1.500**	**0.160**	**0.240**	**0.170**	**18**	**18**	**0**	**440**
Upstream site on Twin Watershed receiving tributary (Site #2)	02-26-00	7 26	5	0 774	0 667	0 107	0 605	6 40	5 90	0 500	2 9	2 4	0 020	3 480	3 500	26	26	0	60
	Mean	**7.26**	**5**	**0.774**	**0.667**	**0.107**	**0.605**	**6.40**	**5.90**	**0.500**	**2.9**	**2.4**	**0.020**	**3.480**	**3.500**	**26**	**26**	**0**	**60**
Twin Watershed Zero-till Field Weir (Site #3)	02-22-00																		< 10
	02-23-00	6 87	10	1.810	1.700	0 110	1.610	6 20	5 40	0 800	2.700	1.900	0 080	3 590	3 500	21	20	1	10
	02-26-00	6 73	6	1 980	1 820	0 160	1 730	7 74	6 74	1 000	3 200	2 200	0 050	4 710	4 540	21	21	0	< 10
	Mean	**6.80**	**8.000**	**1.895**	**1.760**	**0.135**	**1.670**	**6.970**	**6.070**	**0.900**	**2.950**	**2.050**	**0.065**	**4.150**	**4.020**	**21.000**	**20.500**	**0.500**	**10**
Downstream site on Twin Watershed receiving tributary (Site #1)	02-22-00		36	1.700	1 520	0 180		6 25	4 75	1 500	3 800	2 300	0 580		2 450		20		
	02-22-00		9	1 580	1 510	0 070		5 19	4 59	0 600	2 900	2 300	0 520		2 290		19		5100
	02-23-00	6 96	6	1 710	1 580	0 130	1 480	6 13	4 63	1 500	3 000	1 500	0 180	3 190	3 130	20	21	0	1260
	02-26-00	7 24	6	0 870	0 753	0 117	0 682	6 76	5 76	1 000	3 100	2 100	0 020	3 720	3 660	25	25	0	250
	Mean	**7.10**	**14.250**	**1.465**	**1.341**	**0.124**	**1.081**	**6.083**	**4.933**	**1.150**	**3.200**	**2.050**	**0.325**	**3.455**	**2.883**	**22.500**	**21.250**	**0.000**	**1172**

Blanks = No data.

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen.

Note: Negative values for particulate calculation sometimes occurred where total concentrations were less than dissolved values. These differences were very small and result from analytical variatons

Fecal coliform mean values based upon geometric means.

Appendix 10a. Mean, minimum, and maximum values for water quality data collected from the Natural Wooded Area, Manured Watershed, Conventional-till and Zero-till field sites during spring runoff 2001. (Water analyses done at the Envrionment Canada Laboratory in Saskatoon, Saskatchewan.)

Station	Season		Suspended Solids	Phosphorus				Nitrogen					Organic Carbon		
				Total	Dissolved	Particulate	Orhto-	Total	Dissolved	Particulate	Ammonia	Nitrate-nitrite	Total	Dissolved	Particulate
			(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)	(mg L⁻¹)
Natural Wooded Area (Site #10)	Spring Runoff	**Min**	1.0	0.076	0.062	0.004	0.063	0.376	0.363	0.010	0.023	0.100	4.33	4.27	0.06
		Max	42.6	0.197	0.090	0.108	0.077	1.281	0.622	0.659	0.076	0.267	14.70	9.10	5.60
		Mean	**8.53**	**0.105**	**0.078**	**0.027**	**0.072**	**0.601**	**0.470**	**0.130**	**0.042**	**0.187**	**6.930**	**5.847**	**1.084**
Manured Watershed Weir (Site #7)	Spring Runoff	Min	7.6	0.686	0.591	0.095	0.524	2.338	1.850	0.409		0.577	11.36	8.93	2.36
		Max	21.6	0.995	0.894	0.101	0.856	4.279	3.870	0.488		2.310	15.86	13.50	2.43
		Mean	**14.60**	**0.841**	**0.743**	**0.098**	**0.690**	**3.309**	**2.860**	**0.449**		**1.444**	**13.610**	**11.215**	**2.395**
Twin Watershed Conventional-till Field (Site #4)	Spring Runoff	Min	10.4	0.565	0.491	0.074	0.386	3.947	2.770	0.307	0.589	0.869	11.70	8.68	1.48
		Max	340.0	4.490	4.190	0.300	2.180	19.925	19.300	2.360	1.920	14.600	35.90	21.60	19.50
		Mean	63.62	1.451	1.354	0.097	0.762	6.862	6.147	0.715	0.812	3.717	18.769	13.796	4.973
Twin Watershed Zero-till Field (Site #3)	Spring Runoff	Min	1.6	1.500	1.400	0.020	1.230	0.731	0.159	0.224	1.070	0.569	10.73	8.86	1.27
		Max	13.2	5.300	5.050	0.320	4.660	14.653	13.900	0.753	2.230	7.320	30.35	26.70	3.71
		Mean	7.62	2.663	2.535	0.129	2.189	5.913	5.511	0.403	1.319	2.685	17.412	15.281	2.130

Blanks = No data.

Note: Inquiries about availability of raw data should be made to Environment Canada Laboratory, NHRC, 11 Innovation Blvd, Saskatoon SK S7N 3H5.

Appendix 10b. Water quality data collected from the Natural Wooded Area, Forage-Field, and the Manured Watershed field sites during spring runoff 2001. (Water analyses done at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
	(mm/dd/yy)	(Units)	(mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	Ortho- (mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	Total Kjeldahl (mg L^{-1})	Dissolved Kjeldahl (mg L^{-1})	Ammonia (mg L^{-1})	Nitrate-nitrite Soluble (mg L^{-1})	Nitrate-nitrite dissolved (mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	(No 100mL^{-1})
Natural Wooded Area (Site #10)	03-22-01	8.07	< 5	0.104	0.101	0.003	0.077	0.39	0.49	0	0.3	0.4	0.020	0.090	0.150	1	2	0	< 10
	03-29-01	7.99	< 5	0.105	0.108	0.000	0.078	0.46	0.36	0.100	0.3	0.2	0.020	0.160	0.170	4	4	0	< 10
	04-05-01																		< 10
	Mean	**8.030**	**< 5.00**	**0.105**	**0.105**	**0.001**	**0.078**	**0.425**	**0.425**	**0.000**	**0.300**	**0.300**	**0.020**	**0.125**	**0.160**	**2.500**	**3.000**	**0.000**	**10.0**
Forage Field (Site #9)	03-20-01	7.28	11.0	2.220	2.090	0.130	2.030	4.10	3.50	0.600	3.6	3.0	1.780	0.500	0.340	10	8	2	210
	03-29-01	7.35	6.0	1.920	1.750	0.170	1.690	2.76	2.66	0.100	2.4	2.3	0.640	0.360	0.370	15	17	0	109
	03-29-01	7.36	7.0	2.280	2.060	0.220	1.990	3.17	2.97	0.200	2.8	2.6	0.760	0.370	0.380	19	19	0	37
	04-03-01	7.12	6.0	1.200	1.100	0.100	0.092	2.43	2.43	0	2.1	2.1	0.360	0.330		22	21	1	80
	04-05-01	6.92	6.0	0.929	0.850	0.079	0.490	2.18	2.08	0.100	1.7	1.6	0.480	0.480		17	16	1	< 10
	04-05-01	6.87	4.0		0.794		0.448	1.70	1.70	0	1.4	1.4	0.430	0.300		13	13	0	< 10
	Mean	**7.150**	**6.67**	**1.710**	**1.441**	**0.140**	**1.123**	**2.723**	**2.557**	**0.167**	**2.333**	**2.167**	**0.742**	**0.390**	**0.363**	**16.000**	**15.667**	**0.667**	**139.0**
Upstream of Manured Watershed Weir (Site #8)	03-20-01	7.38	1000.0	1.880	1.760	0.120	1.700	10.35	9.85	0.500	2.6	2.1	0.490	7.750	7.540	12	13	0	< 10
	03-29-01	7.53	120.0	1.470	1.330	0.140	1.290	9.14	8.14	1.000	3.0	2.0	0.370	6.140	6.400	14	14	0	< 10
	04-03-01	7.32	14.0	1.200	1.200	0.000	0.120	6.30	6.30	0	1.6	1.6	0.540	4.700		15	14	1	< 10
	Mean	**7.410**	**378.00**	**1.517**	**1.430**	**0.087**	**1.037**	**8.597**	**8.097**	**0.500**	**2.400**	**1.900**	**0.467**	**6.197**	**6.970**	**13.667**	**13.667**	**0.333**	**10.0**
Manured Watershed Weir (Site #7)	03-20-01	7.32	9.0	1.030	0.926	0.104	0.895	2.40	1.80	0.600	1.8	1.2	0.370	0.600	0.580	12	11	1	< 10
	03-29-01	7.51	< 5	1.020	0.882	0.138	0.840	2.60	2.30	0.300	2.0	1.7	0.300	0.600	0.620	14	13	1	10
	04-03-01																		< 10
	Mean	**7.415**	**7.00**	**1.025**	**0.904**	**0.121**	**0.868**	**2.500**	**2.050**	**0.450**	**1.900**	**1.450**	**0.335**	**0.600**	**0.600**	**13.000**	**12.000**	**1.000**	**10.0**

Blanks = No data.

Total Nitrogen = calculated from Total Kjeldahl nitrogen + soluble nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + soluble nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note: Negavtive values for particulate calculation sometimes occurred where total concentrations were less than dissolved values These differences were very small and result from analytical variatons

Fecal coliform mean values based upon geometric means.

Appendix 10c. Water quality data collected from the Conventional-till and Zero-till field sites during spring runoff 2001. (Water analyses done at Enviro-Test Laboratories Ltd., Winnipeg, Manitoba.)

Station	Sample Date	pH	Suspended Solids	Phosphorus				Nitrogen								Organic Carbon			Fecal Coliform Bacteria
	(mm/dd/yy)	(Units)	(mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	Ortho- (mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	Total Kjeldahl (mg L^{-1})	Dissolved Kjeldahl (mg L^{-1})	Ammonia (mg L^{-1})	Nitrate-nitrite Soluble (mg L^{-1})	Nitrate-nitrite dissolved (mg L^{-1})	Total (mg L^{-1})	Dissolved (mg L^{-1})	Particulate (mg L^{-1})	(No 100mL $^{-1}$)
Upstream site on Twin Watershed receiving tributary (Site #2)	04-03-01 04-05-01	7 36	7 0	0 350	0 340	0 010	< 0 001	4 80	4 80	0	0 8	0 8	0 280	4 000		13	13	0	< 10 < 10
	Mean	**7.36**	**7.00**	**0.350**	**0.340**	**0.010**	**< 0.001**	**4.800**	**4.800**	**0.000**	**0.800**	**0.800**	**0.280**	**4.000**		**13.000**	**13.000**	**0.000**	**< 10**
Conventional-till field Weir (Site #4)	03-29-01 04-03-01 04-05-01	7 20	22 0	0 800	0 600	0 200	0 073	4 90	4 90	0	2 9	2 9	0 730	2 000		22	22	0	< 10 < 10 < 10
	Mean	**7.20**	**22.00**	**0.800**	**0.600**	**0.200**	**0.073**	**4.900**	**4.900**	**0.000**	**2.900**	**2.900**	**0.730**	**2.000**		**22.000**	**22.000**	**0.000**	**< 10**
Twin Watershed Zero-till Field Weir (Site #3)	03-20-01 03-29-01	7 25	13 0	4 860	4 730	0 130	4 540	14 57	13 37	1 200	7 500	6 300	3 840	7 070	6 860	30	31	0	20 10
	04-03-01 04-05-01	7 35	3 0	2 900	2 600	0 300	1 200	4 68	4 68	0	4 400	4 400	1 100	0 280		28	28	2	< 10 < 10
	Mean	**7.30**	**8.00**	**3.880**	**3.665**	**0.215**	**2.870**	**9.625**	**9.025**	**0.600**	**5.950**	**5.350**	**2.470**	**3.675**	**6.860**	**29.000**	**28.500**	**1.000**	**11.890**
Downstream	03-29-01	7 30	16 0	2 160	2 100	0 060	1 970	6 89	6 39	0 500	4 000	3 500	1 350	2 890	2 890	18	19	0	20
site on Twin Watershed receiving tributary (Site #1)	03-29-01 04-03-01 04-05-01	7 29	10 0	0 800	0 640	0 160	0 110	5 30	5 30	0	1 300	1 300	0 510	4 000		19	16	3	10 < 10 < 10
	Mean	**7.30**	**13.00**	**1.480**	**1.370**	**0.110**	**1.040**	**6.095**	**5.845**	**0.250**	**2.650**	**2.400**	**0.930**	**3.445**	**2.890**	**18.500**	**17.500**	**1.500**	**11.890**

Blanks = No data.

Total Nitrogen = calculated from Total Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Total Dissolved Nitrogen = calculated from dissolved Kjeldahl nitrogen + dissolved nitrate-nitrite nitrogen

Particulate Nitrogen = calculated from total nitrogen - dissolved nitrogen

Note: Negative values for particulate calculation sometimes occurred where total concentrations were less than dissolved values. These differences were very small and result from analytical variatons

Fecal coliform bacteria mean value based upon geometric mean.

Appendix 11. Matrix showing significant ($p < 0.05$*) comparisons between sites from Analyses of Variance pairwise comparisons for nutrient, organic carbon, and supsended solid data from the Manured Watershed field, Zero-till field, Conventional-till Forage Field, and the Natural Wooded Area in the South Tobacco Creek Watershed, 1998 - 2000.

Variable	Year	Pairwise Comparisons									
		MW/ZT	MW/CT	MW/FF	MW/NWA	ZT/NWA	CT/NWA	FF/NWA	ZT/CT	ZT/FF	CT/FF
TOC	1998	*				*					
	1999										
	2000	ND	ND	ND	ND	*	ND	*	ND		ND
	2001	*			*	*	*	*			
DOC	1998	*	*		*						
	1999							*		*	*
	2000	ND	ND	ND	ND	*	ND	*	ND		ND
	2001				*	*	*	*			
TN	1998	*	*	*	*	*	*			*	*
	1999		*		*	*	*	*	*		*
	2000	ND	ND	ND	ND	*	ND	*	ND	*	ND
	2001				*	*	*	*		*	*
DN	1998	*	*	*	*	*	*			*	*
	1999			*	*	*	*				*
	2000	ND	ND	ND	ND	*	ND	*	ND	*	ND
	2001				*	*	*	*			
NH3	1998	*	*	*	*	*	*		*	*	*
	1999				*	*	*	*			
	2000	ND	ND	ND	ND	*	ND	*	ND		ND
	2001	ND	ND	ND	ND	*	*	*	*	*	
NO3/NO2	1998	*	*	*	*	*	*	*	*	*	*
	1999				*	*	*			*	*
	2000	ND	ND	ND	ND	*	ND		ND	*	ND
	2001				*	*	*			*	*
TP	1998	*		*	*	*					
	1999				*	*	*	*			
	2000	ND	ND	ND	ND	*	ND	*	ND		ND
	2001				*	*	*	*	*		
DP	1998	*	*	*	*	*	*				
	1999		*		*	*	*	*	*		*
	2000	ND	ND	ND	ND	*	ND	*	ND		ND
	2001	*			*	*	*	*	*		
SS	1998		*			*		*	*		*
	1999						*		*	*	*
	2000	ND	ND	ND	ND		ND		ND		ND
	2001						*		*		*

ND = No data.

* denotes a signifcant difference ($p < 0.05$) occurred between ANOVA Bonferroni pariwise comparisons.

TOC = Total organic carbon; DOC = Dissolved inorganic carbon; TN = Total nitrgen; DN = Dissolved nitrogen; NH3 = Ammonia nitrogen; NO3/NO2 = Nitrate-nitrite nitrogen; TP = Total Phosphorus; DP = Dissolved phosphorus

MW = Manured Watershed field; ZT = Zero-till field; CT = Conventional-till field; FF = Forage Field; NWA = Natural Wooded Area.

Appendix 12. Matrix showing significant ($p < 0.05$*) comparisons between years from Analyses of Variance pairwise comparisons for nutrient, organic carbon, and supsended solid data from the Manured Watershed field, Zero-till field, Conventional-till Forage Field, and the Natural Wooded Area in the South Tobacco Creek

Location	Variable	Bonferroni Pairwise Comparisons					
		98/99	98/00	98/01	99/00	99/01	00/01
MW	TP		ND		ND		ND
	DP	*	ND		ND		ND
	TN	*	ND	*	ND		ND
	DN	*	ND	*	ND		ND
	NH3	*	ND	ND	ND	ND	ND
	NO3/NO2	*	ND	*	ND		ND
	TOC		ND		ND		ND
	DOC		ND		ND		ND
	SS		ND		ND		ND
ZT	TP	*	*	*	*	*	
	DP		*	*	*	*	
	TN	*	*	*			
	DN	*	*	*			
	NH3			*			
	NO3/NO2	*	*	*			
	TOC	*	*	*			
	DOC	*	*	*	*	*	
	SS	*				*	
CT	TP		ND	*	ND	*	ND
	DP	*	ND	*	ND	*	ND
	TN	*	ND	*	ND	*	ND
	DN	*	ND	*	ND	*	ND
	NH3		ND	*	ND	*	ND
	NO3/NO2	*	ND	*	ND		ND
	TOC	*	ND	*	ND		ND
	DOC		ND	*	ND	*	ND
	SS		ND		ND	*	ND
FF	TP			*			
	DP	*		*			
	TN						
	DN						
	NH3						
	NO3/NO2						
	TOC						
	DOC						
	SS	*		*			
NWA	TP						
	DP						
	TN	*		*			
	DN						
	NH3						
	NO3/NO2	*				*	
	TOC			*			
	DOC			*			
	SS						

ND = No data.
* denotes a signifcant difference ($p < 0.05$) occurred between ANOVA Bonferroni pariwise comparisons.

TOC = Total organic carbon; DOC = Dissolved inorganic carbon; TN = Total nitrgen; DN = Dissolved nitrogen; NH3 = Ammonia nitrogen; NO3/NO2 = Nitrate-nitrite nitrogen; TP = Total Phosphorus; DP = Dissolved phosphorus

MW = Manured Watershed field; ZT = Zero-till field; CT = Conventional-till field; FF = Forage Field; NWA = Natural Wooded Area.